Innovating in public

The introduction of LED lighting in Berlin and Lyon

vorgelegt von
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Nona Schulte-Römer, Berlin, 05.10.2014

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Berlin, November 2015

Table of contents

Copyright notice

List of figures

List of Tables

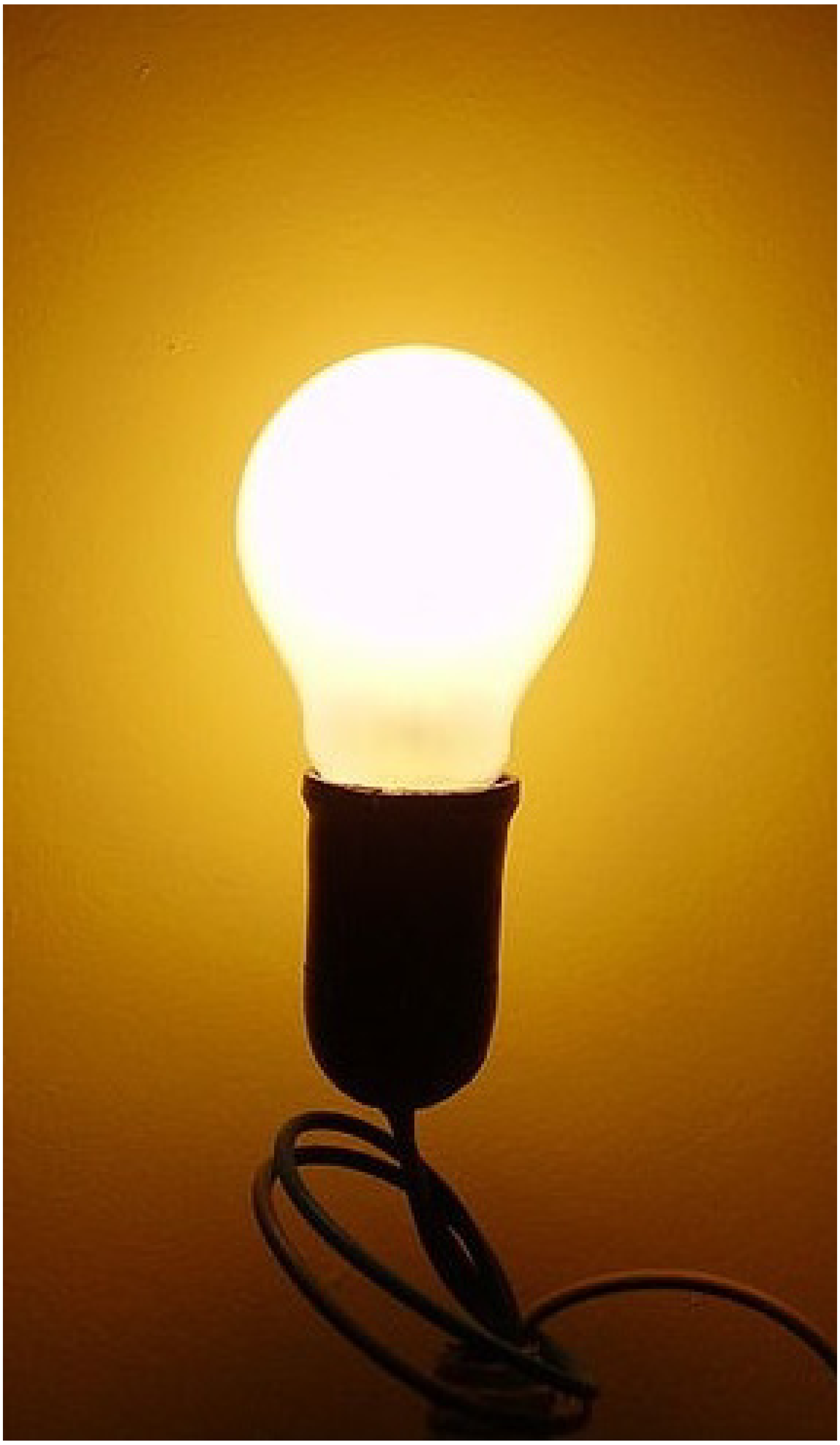

Figure 1-1: For copyright reasons I cannot display the results of the online image search mentioned on the next page. However, I invite the reader to try it herself/himself. Photo (CC).

1. Introduction: Innovating in public?

Anyone who does an online image search for the term ‘innovation’ will be struck by the omnipresence of a very familiar object: More often than not, the conventional light bulb is used to symbolise the moment of innovation. This semantic relationship is peculiar. After all, it has been more than a hundred years since electric lighting was invented and the light bulb is about to be superseded by *electronic light-emitting diodes*, in short LEDs. So I wonder what will happen to this internet image search. Will LEDs replace our beloved symbol of innovation and how long will it take? Of course, this is a purely speculative question.

In this work I will focus on a more tangible but equally present problem, namely the question of *how LED lighting is introduced in cities,* or more precisely how it is introduced *in public lighting.* In the process of exploring this question, I have come to realise that the topic of public lighting is boring to many. In this study I hope to open a perspective that shows that quite the opposite is the case. Public lighting is a multi-faceted phenomenon, simultaneously invisible and shining and particularly exiting in times of technological transition.

LEDs have been around for a while. We know them as the technology behind little control lamps, Christmas lighting or display illumination. Most of us are aware that LEDs are a highly efficient light source, but only few of us would recognise the new light if it was installed in our streets. Yet this is exactly what is happening at the moment. LED technology is being installed on the streets of European cities. The lighting industry calls it a revolution in lighting comparable to the introduction of electric lighting (cf. The Climate Group, 2012-06). And the luminous efficacy of LEDs, that is the ratio of power input and light output, is truly impressive. Compared to incandescent light bulbs, which emit beautiful light but also a lot of heat, today’s tiny diodes can produce up to ten times more visible light per Watt, with a lot of upside potential. Nevertheless, the phasing out of light bulbs from the European market has stirred public debates about bad light quality. Obviously, environmental and cost concerns are not all that matter in lighting. The Europeans’ love of the light bulb makes this very clear. It also shows that lighting is no longer boring when it concerns the illumination of our living rooms. Similarly, the first outdoor installations of cool-white LED lighting in urban streets prompted complaints from citizens, especially in northern Europe. Yet LEDs are not only very efficient but are also the most flexible light source on the market. They are dimmable, have a customisable light distribution and thus allow for innovative approaches in public lighting that are yet to be explored. This work will explore what this means for us, and how the introduction of this revolutionary electronic light source might affect or transform our familiar worlds and nocturnal life in European cities. While the general public has, so far, taken little notice of the turbulence in the lighting market, innovators such as industrial actors, scientists and governments are well aware of the opportunities and challenges associated with semiconductor light sources.

From the innovators' perspective, LED lighting is a 'disruptive technology' (Thomond, Herzberg, & Lettice, 2003, p. 2). In 1999, US researchers suggested that '*this new white light source would change the way we live, and the way we consume energy*' and called for concerted national action (Roland Haitz, Kish, Tsao, & Nelson, 1999, pp. 1, emphasis in the original). Since then, governments across the globe have come to share the excitement about solid-state lighting (SSL), a more general term for LED technology, and the innovation is being pushed and further developed in national 'systems of innovation' (cf. B.-A. Lundvall, 1992). Cities have thereby been assigned an important role. As potential early adopters they are incentivised to deploy LED products and thus create lead markets for SSL technology. Such demand-side innovation policies are also coupled with environmental objectives and climate-change mitigation policies.

In December 2011, the European Commission published the Green Paper titled 'Lighting the Future' to advance the market uptake for SSL technology in Europe. 'Expanding LED lighting is a "no-brainer"', explained the European Commission's Vice President, Neelie Kroes. 'It means more money in your pocket, and a healthier planet.' Indeed, the new technology offers great opportunities in both respects. According to the European Commission, lighting accounts for about 50 per cent of the municipal electricity consumption of European cities. In a 2013 follow-up report, the European Commission argued that up to 70 per cent of that energy could be saved and that energy and maintenance costs could be significantly reduced through the implementation of intelligent LED-based lighting systems (2013-06, p. 7).

In line with these projections, municipal LED pilot projects show that the energy-saving potential of LED lighting is enormous, especially if the new technology is installed in combination with telemanagement systems that allows them to be dimmed and controlled 'intelligently'. Municipalities are nevertheless still sceptical, ignorant or hesitant to install the promising but expensive equipment on their streets. LED technology is still developing at a high speed and is fraught with uncertainties. Quality standards for evaluating and comparing products are still in the making. Empty public purses are also an important and often decisive constraint when it comes to modernising lighting infrastructures. LED technology is also not the only possible solution to outdated infrastructures. Municipalities have the choice between similarly efficient proven high-intensity discharge technology (HID) and an innovative electronic light source which also requires new skills and know-how from its operators. Some communes even argue that they can save more energy and much more money if they switch off their lights.

Innovation policy makers are well aware of the users' reserve and anxieties and are keen to offer information and support. Project evaluation reports and best-practice guides provide facts and give examples on how to deploy the innovation in sustainable ways and in line with urban design or city marketing objectives (DOE, 2013-05-22; European Commission, 2013-06). These reports highlight *exemplary projects* in order to give municipalities a general idea of funding schemes and new technological opportunities. In other words, they highlight the results, potential advantages and also drawbacks of LED lighting. What these reports and practical guidelines do not offer is detailed information about the urban users and their competences, about the concrete planning conditions and the installation processes.

This outcome-oriented information policy is persuasive. Yet it obscures the fact that the successful introduction of the LED innovation takes more than a functioning technology, a realistic business case and political good will. Instead, social-scientific research shows that *users matter* for innovation (Oudshoorn & Pinch, 2003), that their *competence* affects not only installation processes but also product designs (B.-Å. Lundvall, 1985; E. A. von Hippel, 1986) and that the decisions of *representative early users* are decisive for the future market success of new technologies (Mangematin & Callon, 1995). In addition to this, and even more importantly, social-scientific research draws attention to the fact that the introduction of innovations requires *material adaptations* and the *valorisation* of 'the new', not only in market places but also in real-life situations (Akrich, Callon, & Latour, 2002a; Braun-Thürmann, 2005; Hutter & Stark, 2015). In other words, 'the new must be brought into the *familiar world* and enter into exchange with prior *experiences*. It must be *given meaning and evaluated'* (Nowotny, 2008, pp. 2, my emphasis). Against this backdrop, my study aims to *fill the empirical blind spot* regarding the existing local conditions of LED installations and uses by providing detailed insights in six municipal LED projects, their urban key actors and planning processes and their material, social and political situations.

Last but not least, my study also addresses *a conceptual gap* in innovation research, where the messy reality of installation projects has so far received fairly little scholarly attention. Some find it 'surprising' that pilot projects have 'not received more explicit and systematic attention, especially as they involve substantial commitments of public funds' (Harborne & Hendry, 2009, p. 3580). But the lack of interest in this topic is even more surprising in light of the growing academic interest in demand-side innovation and innovative public procurement (Edler & Georghiou, 2007; Edquist, Hommen, & Tsipouri, 2000), 'user innovation' (E. A. Von Hippel, 2005), 'urban laboratories' (Evans & Karvonen, 2014; Karvonen & van Heur, 2014) or 'living labs' (Almirall, Lee, & Wareham, 2012; Pallot, Trousse, Senach, & Scapin, 2010).

With this work I hope to contribute to closing this research gap by conceptualising the introduction of LED technology in real-life situations as *'innovating in public'* and by proposing a conceptual framework for analysing pilot projects, technology trials or 'showcases' of innovation more generally as *early public installations*. This conceptualisation is linked to a twofold change in perspective. First, the emphasis on *installations*—rather than adoption events or implementations—draws attention to the active role of users and their perspective rather than the innovators' perspective. Second, it underlines my pragmatic methodological perspective: The generic notion of early public installations does not specify *a priori* whether an LED project is a technology test or a 'showcase' of innovation. As we will see, this perspective allows us to understand why some projects are later perceived as exemplary LED demonstrations while others are designed to be shown but turn into public trials.

The *testing and showing* of LED lights in the course of their installations is constitutive for the valorisation of innovation in public. It implies that the future of public LED lighting is still unwritten, that the technology is materially and semantically shaped not only in laboratories and markets but also in concrete socio-material situations. It also implies that 'publics' are involved in this 'future-making' (Suchman, Danyi, & Watts, 2008) as benign or critical observers. The histories of past light-technological innovations, like the electric light bulb, support this claim. They also help us understand the particularities of public lighting in the 21st century, which is why I will briefly journey back in history before returning to my research question and the thesis of this work.

Looking back in history, we see that the success of the electric light bulb depended decisively on *observers and wider publics*. The introduction of electric lighting could be retold as a series of public installations, including the technology demonstrations in Thomas A. Edisons' laboratories in Menlo Park, the first experimental real-life installation in New York and the World Fair displays (Gorman & Carlson, 1990; Thomas P. Hughes, 1983; Miettinen, 2006). Edison's success was all but incidental. Instead, he understood how to stage and translate his activities into the 'languages' of varying and heterogeneous audiences (Bazerman, 1999). Furthermore, these demonstrations, which were at times held during public festivities or on pleasure grounds, appealed to wider lay audiences and turned electric lighting into a symbol of progress and innovation (Binder, 1999; David E Nye, 1996).

But the story of the incandescent light bulb also has a less glamourous side: In order to make electric lighting shine, Edison also successfully assembled a network of researchers, investors, engineers who together developed and built electricity infrastructures (Thomas.P. Hughes, 1979; Law, 1991, p. 12). In contrast to the public displays, the infrastructural innovation activities were rather controversial and had to be 'robustly designed' (Hargadon & Douglas, 2001). Underground works were not meant to raise public attention and create surprises. Accordingly, Edison and his team built electricity grids that resembled the existing gas infrastructures and complied with existing urban institutions. This 'invisibilisation' of real-life innovation activities draws attention to the 'invisibility' of urban lighting infrastructures in general.

However, lighting technology was not always invisible and there are still situations when this becomes a public issue. Looking back in history, we can see that the relationship between city lights and citizens has changed fundamentally since the first public lights were introduced.[1] In the 17th century, the task of illuminating urban spaces was performed by citizens or, as in the case of Paris, by the police (Schivelbusch, 1988). As street lighting technologies became larger and more sophisticated, they demanded more skill and systematic coordination (Otter, 2008). With industrialisation, the operation of street lights was institutionalised and delegated, first to lamp lighters and later to ripple control systems. The divide between light experts and lay light users or audiences became definite in the early 19th century with the introduction of gas lighting infrastructures (Clegg, 1853). Since then, lighting infrastructures have been buried underground. Public lighting has become a taken-for-granted public service that is performed by experts and is invisible to those who enjoy the luxury of modern life in industrial cities (cf.Latour & Hermant, 2006 [1998]).

[1] For a detailed overview on 'urban histories of public lighting' see my historical account in the appendix.

Today we are thus faced with a paradoxical situation, in which the artificial lights that shine on us every night and illuminate the public spaces in European cities are no longer a public issue. Public lights are so common and ubiquituous that they are overlooked by most citizens. As a result, the social and cultural need for public lighting—and innovation—is difficult to estimate (cf. Meier, Hasenöhrl, Krause, & Pottharst, 2015). While light in general has *a positive cultural and symbolic connotation*,[2] its *practical value* in our daily lives can be best experienced as loss—when the lights go out (David E. Nye, 2010)—or in times of *technological transition* (cf. Hasenöhrl, 2015).

The introduction of LED lighting in our cities constitutes such a technological transition. The extent to which the innovation is recognised by urban audiences and raises public issues will be explored in this work. This question is even more relevant since LED technology also calls for a re-evaluation of public lighting: The energy-saving potential of LED technology can be best exploited when the innovation is introduced in the form of customised 'intelligent' lighting systems and used adaptively. But to whose needs is it adapted? City lights are a multi-layered phenomenon but, as we have seen, it is also an expert task. Lighting cities requires technological skills and know-how. The quality of public lighting technology is evaluated with regard to photometric criteria and efficiency standards. But light in cities also has a less tangible, incalculable social and cultural dimension. It appeals to our senses and shapes the look and feel of nocturnal urban spaces. It enhances our control over space, our sense of security and facilitates social control in night-time cities. Given these diverse and interrelated managerial, physiological, social, political and cultural dimensions, the introduction of public LED lighting can be understood as a *political issue* that goes well beyond the scope of economic and light-technological criteria. In order to understand what is at stake, this work explores what is evaluated, valued or discredited, and by whom, when LED light is tested and shown in public. We will also see what remains invisible and unquestioned.

My thesis is that the question of *how LED lighting is introduced* does not only depend on industrial product development and marketing or national innovation programmes. Instead, I will show *that urban observers of early public LED installations shape the technological innovation.* Who these observers are and how they are involved in the installation process is thereby an empirical question. However, based on the above, we can already assume that

[2] See Jun'ichiro Tanizaki (1988 [1933]) for an early comparative perspective on the cultural value of light and Karin Hirdina (1997; 2000) or Hartmut Böhme (1997) for more contemporary perspectives.

municipal planners and operators of public lighting infrastructures and their private partners will play a crucial role.

To answer my research question and test my assumptions I have studied the municipal innovation activities around LED lighting in two European cities. Between 2011 and 2013, I conducted multi-sited ethnographic research, including expert interviews, in Lyon, France and Berlin, Germany. Doing so allowed me to take advantage of a historic moment and study the LED innovation *in the making*. The installation of LED street luminaires in European cities has only gathered speed since around 2010. At the time of writing (2014), the technological development of LED technology is still ongoing. The actuality of my research subject has been both a challenge and motivation.

This work is structured as follows. *Chapter 2* starts with a clarification of my sociological perspective on innovation, technology and cities. Subsequently I will develop a conceptual framework for analysing the real-life situations in which innovation, technology and cities come together. Since my research interest calls for a micro-analytic perspective on LED projects, I ruled out a number of theoretical approaches, such as multi-level perspectives that conceptualise innovation projects as niches (Geels & Schot, 2007; Kemp, Schot, & Hoogma, 1998) or producer-biased demand-side innovation perspectives (Lember, Kalvet, & Kattel, 2011; Uyarra & Flanagan, 2010). Economic and policy-oriented studies on state-funded innovation projects were more instructive, but they conceptualise these projects in terms of diffusion and only with regard to their economic effects (W. S. Baer et al., 1976; Myers, 1978). I therefore contrasted these innovation studies with social-scientific approaches, particularly pragmatic and pragmatist studies on technology implementation processes (Akrich et al., 2002a; Akrich, Callon, Latour, & Monaghan, 2002b; W. Bijker, 1992; Rammert, 1990) (Suchman, 2012). Furthermore, I drew on the social-scientific literature on public experiments and scientific knowledge production (Gieryn, 2002; Groß, Hoffmann-Riem, & Krohn, 2005; Karvonen & van Heur, 2014; Krohn & Weyer, 1994). Based on these studies I will specify my assumptions about the introduction of new technologies in real-life situations and develop a conceptual framework for analysing LED projects in terms of testing and showing. This framework will be outlined at the end of chapter 2, where I will also explain in more detail how my shift in perspective is reflected in the notion of 'early public installations'.

In chapter 3, I will outline how I translated this conceptualisation into a research strategy. While my data collection method was *ethnographic* (Marcus, 1995a), my data analysis was inspired by Adele Clarke's *situational analysis* (2003). Her 'post-essentialist' continuation of grounded theory methodology (Glaser, Strauss, & Strutzel, 1968) is perfectly suited to exploring the socio-material interactions in the course of planning processes and the emerging configurations of LED technology in use. After introducing my methodology, I will offer insights into my research and case selection process, describe how I coded and mapped my data and provide a critical reflection on my approach. The results of this grounded, situational approach are six 'thick analyses' of LED projects (cf. Fosket, 2002). In these analyses, I simultaneously studied global, urban and project-specific LED-related issues and matters as they were enacted in 'messy' planning situations (A. E. Clarke, 2003). In the subsequent three chapters I will present these findings in a more ordered way, starting with global developments around urban public lighting.

In chapter 4, the LED innovation will enter the scene as the most relevant global development in this work. I will outline what makes this new lighting technology special, how it has developed since the 1960s and why it is perceived as a disruptive innovation. Based on my empirical findings, I will describe the innovation from the perspective of municipal and private technology users and explain the wider political situation. We will see that LED technology not only pushes but is also pulled by other global light-related developments, such as technical standards, urban policy innovations such as 'nocturnal urbanism' and, most importantly, global climate-change concerns and national mitigation policies. However, as we will see in the subsequent chapter these global developments affect urban realities in different ways.

In chapter 5, we will 'familiarise' the reader with the urban situations of Lyon and Berlin starting with some light-related geographical and 'tourist' information on the urban nightlife and cultural attractions, such as the Fête des Lumières and the Berlin gaslights. The two cities could not be more different. While Lyon has an image as a 'City of Light' and is, according to its citizens, quite rich and conservative, Berlin is, according to its current mayor, poor and sexy and comparatively dark at night. These city images, their financial and their infrastructural situations define what I conceptualise as *urban public lighting networks*, which include actors and infrastructures. It also affects the cities' lighting strategies as they are laid out in their light plans. In the subsequent chapters we will see how ‘the cities’ and also ‘the global’ are enacted in concrete ‘local’ situations.

In chapter 6, we will finally come to the core of this study: Six case studies on early public LED installations. What the cases share is that they all involve the installation of LED luminaires at a time when their local users had still no or very little practical experience with the new technology. They were therefore fraught with uncertainties and the new. Accordingly, the project planners designed their installation either as *technology tests* or as *showcases of innovation*. In chapter 6, I will reconstruct the six planning processes and the public impression they made. As we will see, every case has its own story, its own key actors and artefacts and its own observers, which provides interesting variety for the subsequent case comparison.

In chapter 7, I will compare the six case studies and relate them to my conceptual framework as outlined in chapter 2. My findings challenge the idea that the installation of technological innovations can be projected and designed as either a technology trial or a demonstration project. Instead, they show that the projects developed between the poles of testing technology and showing innovation. In line with my theoretical assumptions, these *test-show trajectories* are closely related to the key actors’ capacities to manage heterogeneous urban public lighting networks and the ‘publicness’ of their innovation activities. In addition to that, my case comparison revealed *city-specific patterns of testing and showing*, which will be explained in the second part of my analysis with reference to the urban public lighting networks as outlined in chapter 5.

In chapter 8, I will summarise my findings and their analytical implications in order to reconsider what it means to innovate in public. I will also draw some theoretical and practical conclusions, for innovation researchers and light planners and remind myself and the reader of the limitations of this work. These are most obvious when one looks at the appendix.

In chapter 9, I buried one of my ‘killed darlings’—an overview of the last 400 years of urban public lighting, starting with oil lamps and candles in the 17th century. The chapter describes the coevolution of artificial public lighting and cities and outlines the continuities and changes. This historical research was an important basis for my study as it helped me to understand the particularities of present developments and to put the ‘LED revolution’ into perspective.

I conclude this introductory chapter with a few words about my research journey—to pay tribute to my post-essentialist approach and make my research perspective more transparent. I first became interested in urban lighting in 2008/2009. With an academic background was in theatre sciences, political and cultural sciences, I was interested in architecture and cities but had never cared about, or paid attention to public lighting. City lights first piqued my interest in the form of LED media facades, when I was looking for a research topic for my dissertation within the framework of my research unit 'Cultural Sources of Newness' at the WZB. I was soon intrigued by the multi-layered and ambivalent phenomenon of light, which my former aesthetics professor Karin Hirdina described as 'beautiful and dangerous' (2000). I was fascinated by its potential to transform and enhance control in and over social spaces (Barthes, 1990; cf.Schivelbusch, 1987; Schulte-Römer, 2011a, 2013e). And there was so much more 'newness' under way than the so-called LED revolution. Although I had to make a research choice, I have never forgotten that urban lighting is a field of overflowing and interrelated newness. Hopefully, the reader will find traces of this fascination for city lights in general in this study on their most mundane appearance, in the form of public street lights.

2. Concepts and theory

This study relates to innovation, technology and cities. All three subjects constitute independent social-scientific research areas and have been conceptualised in very different ways. I will therefore begin this chapter by clarifying how I approach these three interrelated phenomena (2.1). Second, my research focuses on events that are commonly referred to as pilot projects or innovation 'showcases'. As I will outline in the next step (2.2) they can also be conceptualised in different ways: as a *stage in the innovation process*, as *configurations in socio-material networks* and as *places of evidence production*. All three approaches offer relevant insights, in particular social-scientific studies on science, technology and society (STS). These studies are transdisciplinary, share a micro-analytic perspective and highlight the contingent material, social and cultural dimensions of technological development and evidence production. Methodologically they are thus perfectly suited to analysing light-technological *innovation in the making*. They are also analytically salient for my project, as many of these studies focus on similar situations in which innovators, technical artefacts, technology users, urban infrastructures and spaces, publics and even lighting technology also play a role. The chapter ends with a clarification of my key concepts (2.4), such as 'early public installations' and 'testing and showing' in 'socio-material networks'.

2.1 Some clarifications: Innovation, technology and cities

'Innovation' has become a 'semantically ubiquitous', positively connoted buzzword (Rammert, 2010, p. 35).[3] Innovations drive our growth-based economy and are strongly associated with technological development. According to the OECD, innovation can be defined—and quantified or measured—as 'the implementation of a new or significantly improved product (good or service)…' (2005, p. 46).[4] Similarly, the Oxford Handbook of Innovation distinguishes between 'inventions' as 'the first occurrence of an idea for a new product or process, while innovation is the first attempt to carry it out into practice' (Fagerbarg, Mowery, & Nelson, 2005, p. 4). In this sense, the act of implementation transforms inventions into innovations. In contrast, sociological perspectives define

[3] 'Innovation' was not always as desirable as it is today. Benoît Godin (2008) shows that the 'category' has undergone a semantic change (cf. Knoblauch, 2013).

[4] The definition goes on: '…(or process, a new marketing method, or a new organizational method in business practices, workplace organisation or external relations.) I have stopped here since in OECD terms, LED lighting qualifies as a product innovation (2005, p. 48).

innovation more broadly,[5] for instance as the valorisation of inventions (Marz, 2010) or acts of valuation in the face of uncertainty. '[S]omething new is entering the world, and someone, or some group in society has to determine its worth, its dangers, and its potential' (Hutter & Stark, 2015, p. 1) In this sense we can understand innovations as 'material or symbolic artefacts which observers perceive as new and experience as an improvement on what already exists' (Braun-Thürmann, 2005, p. 6).[6] Innovation can thus be defined as a performative act of value attribution that transforms something that has been unknown and irrelevant into a relevant fact or artefact with social implications.[7] In the context of technological innovation, typical 'moments of valuation' (Berthoin Antal et al., 2015) are efficiency tests, risk assessments or demonstrations (Maasen & Merz, 2006; Schot & Rip, 1997; Simakova, 2010; W. Smith, 2009).

This sociological perspective on innovation *does not specify who enacts and observes 'the new'*, which is particularly relevant for my study. In contrast to the above-mentioned macro-economic definitions, the sociological definition does not imply that invention takes place in laboratories and firms and that the resulting products are valorised in markets. Furthermore, the sociological perspective does not limit its focus to technological innovations but also accounts for invention and valorisation in other domains than the economy. There is growing criticism of the technology-biased and economy-oriented character of innovation research. A number of German sociologists have already proposed more general concepts like 'social innovation' (Aderhold & John, 2005; Zapf, 1989) or developed generic criteria for conceptualising and analysing innovation in different domains of our society (Hutter et al., 2010; Rammert, 2010).[8] While innovation stands for 'creative deviation and uncertain potentials', technology stands for 'routines and taken-for-granted resources' (Rammert, 2008, pp. 7, my translation).

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[5] For an overview with sociological underpinnings see (Aderhold & John, 2005; Blättel-Mink, 2006; Braun-Thürmann, 2005).

[6] See also Hutter (2010, p. 8) for an overview on comparative definitions.

[7] Valuation or valorisation—I use these terms synonymously—are not only a productive sense-making activities. These acts also involve the devalorisation, negotiation or even destruction of what was considered valuable before (Berthoin Antal, Hutter, & Stark, 2015; W. E. Bijker, Hughes, & Pinch, 1987; Schumpeter, 2006).

[8] Rammert proposes a framework for analysing innovation as change in semantics, practices and grammatics such as rules and resources. In my research unit, the 'Cultural Sources of Newness' unit at the WZB Berlin Social Science Research Center we started our work from the thesis that innovation processes are shaped by 'forms of propinquity, collaboration and communication that surround innovation processes' in specific 'cultural configurations' (Hutter et al., 2010, p. 7). The graduate program 'Innovation Society Today', which I was associated with, 'places the purportedly new *reflexive quality* of actions, orientations, and institutions, *both as an overarching and cross-cutting social phenomenon*, at the center of its analysis' (Hutter, Knoblauch, Rammert, & Windeler, 2013, p. 3).

Technologies can be understood in three ways, as artefacts, procedures or systematised knowledge (cf. Rammert, 2010, p. 292), I therefore distinguish between LEDs as a light source, LED lighting and LED technology, see chapter 4.[9]

From a sociological perspective, technological artefacts are also *performative social facts* in the sense that 'they are products of previous social activity and producers of future social activity. […] Once installed and institutionalized they exert constraints on the individual's thoughts and actions' (Rammert, 1997b, pp. 173-174).[10] These constraints are usually outweighed by the expected instrumental utility of technological artefacts, procedures or knowledge.[11] A technology is '*a configuration that works'* (Rip & Kemp, 1998, pp. 330, orginial emphasis). Technologies facilitate our everyday lives in culturally specific ways. They also shape social spaces (Appadurai, 1988; Barry, 2001). Public lighting, which is also part of so-called large technological systems (LTS) (Thomas P. Hughes, 1987), is a perfect example.

Artificial city lights also exemplify the symbolic dimension of technology or technological imaginaries (David E Nye, 1996). Since industrialisation, they have become a characteristic feature of urban spaces (see 9.2. for an overview or Otter, 2008; Schivelbusch, 1988). To the present day they are associated with modernity and prosperity (Besecke & Hänsch, 2015; Binder, 1999),[12] which is most obvious in places where street lighting is not present, for instance in developing countries. Professionalised as urban lighting infrastructures are today in European cities,[13] they have become part of those 'now-familiar, socio-technological

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[9] Rammert argues that the elision of the difference between 'techniques', as instrumental procedures in the narrower sense, and 'technologies', as the body of knowledge that produces technological artefacts (i.e. the. engineering sciences), corresponds with the character of modern 'high technologies' like computer science or genetic engineering. Here, 'the production of scientific knowledge and the production of technological instruments is closely interrelated' (Rammert, 1999, pp. 3, my translation).

[10] With reference to Anthony Gidden's work, Rammert therefore further argues that technologies 'should be considered more generally as 'techno-structures' within the stream of social action rather than single and separate material means outside of society' (Rammert, 1997b, p. 173).

[11] In STS, the instrumental logics of technological artefacts are also controversially discussed in terms of 'politics'. Prominent examples of this debate include Langdon Winner's study 'Do artifacts have politics?' (1980), which prompted Bernward Joerges to counter 19 years later 'Do politics have artefacts?'(1999). Roel Nahuis and Harro van Lente offer an excellent overview and argue: 'The politics of technology involves displacements between various interrelated settings ranging from the context of design to the context of use. Not only parliaments, councils, and forums accommodate political practices, but also laboratories (Latour, 1987), experiments, demonstrations (W. E. Bijker et al., 1987; Rip & Schot, 2002)[…]. This variety of settings and their particular characteristics raise questions about the democratic quality of technological innovation.' (2008, p. 559).

[12] The connection seems so 'obvious' that economists take nocturnal satellite pictures as a proxy for the economic prosperity of cities or regions—the brighter the lights, the more developed.

[13] As outlined in more detail in chapter 9, early public lighting was maintained by citizens (Ekirch, 2005; Schivelbusch, 1988).

assemblies we take for granted' (Guy, Graham, & Marvin, 1997, p. 194) and are 'black-boxed'.

The notion of 'black-boxing' is frequently used in STS to describe processes of socio-technical delegation or representation (Callon & Latour, 1981). 'Black-boxed' technologies are routinised interactions between actors and artefacts that make us overlook the individual steps involved. Effective acts of delegation 'dislocate co-presence' from human social relationships and thus make social life appear less complex although 'it is almost always more complicated' (Latour, 1996b, p. 233). In the case of human-machine interactions, such processes are often literally put away in boxes. LED lights are switched on and we forget about the series of large-scale and nano-scale coordination processes it takes to illuminate our cities, which brings us to my last point.

Cities are unthinkable without technologies. As we have seen, urban infrastructures—including lighting systems, electricity grids, but also water and mobility networks—are constitutive of life in cities (Graham & Marvin, 2008). So is architecture, which shapes urban spaces and city images in contingent but recognisable ways—by day *and* night (Delitz, 2010; McQuire, 2005, 2008; Venturi, Scott Brown, & Izenour, 1977). To put it more radically, urban spaces, like all social spaces, do not exist independently of the technologies we use to create, maintain, represent and perceive these spaces (Law, 2002).

Contemporary sociological perspectives on cities therefore reject essentialist notions of urban spaces as geographic territories that *contain* people and things (Löw, 2000; Schroer, 2006). Instead, spaces are produced and reproduced—through unique interventions like building projects or city marketing campaigns (Reckwitz, 2009; L. Rogers, 2005), in mundane ways by the citizens who inhabit, visit, use and talk about urban spaces and places (de Certeau, 1984; Lefebvre, 1991) or through the circulation and assemblage of artefacts, actors and imaginaries (Amin & Thrift, 2002; Farías & Bender, 2010).

As such, cities can be understood as 'obdurate' social facts (Hommels, 2005a). Like their technologies, they are shaped by their planners' and users' views and practices and their shared 'persistent traditions', for instance planning paradigms (Hommels, 2005b). Finally, they are also embedded, entangled and enacted through local as well as global relations between people and things (Castells, 1989; Sassen, 1991).

Against this background, I characterise my perspective on Berlin and Lyon as relational, non-holistic and non-essentialist. I have no intention to follow all these relations or to describe 'the city' as a socially, economically, culturally, politically and historically structured or structuring entity (Berking & Löw, 2008; Jacobs, 1984; Scott & Soja, 1996). Instead, my aim is to understand how aspects of cities—governance arrangements, city images, lifestyles, etc.—are enacted and evoked when LED technology is introduced in urban spaces. In *theory*, I am prepared to find 'obduracy' (Hommels, 2005a), 'splintering networks' (Guy et al., 1997) and 'global streets' (Sassen, 2011). The *empirical* question is which actors, artefacts and imaginaries are mobilised to bring the new light into the familiar worlds of Berlin and Lyon, and who valorises, overlooks or rejects the innovation.

To conclude, I can specify my research question based on my relational perspective on innovation and technology. First, we have seen that *innovations* are performed or co-produced by observers who perceive the 'new and better'. This becomes more likely if the supposed *innovation is shown* in front of audiences. Second, I have highlighted the instrumental character and value of technology. Technological artefacts, procedures and knowledge are expected to fulfil predefined and specific functions and are evaluated in line with these expectations. These cause-effect relationships are eventually taken for granted or black-boxed—at least as long as the configuration works. Yet in implementation processes, their workability has not been established and proven (cf. Maasen & Merz, 2006; Schot & Rip, 1997). Therefore, *technology is tested*. Technology assessments are 'pragmatic' in the philosophical sense (Rammert, 2009), as they are performed in concrete interactions with observable real-life effects, in laboratories or streets. Furthermore, testing technology in use is a multifaceted activity. It can concern the performance of an artefact, the efficiency of procedures or the applicability of knowledge. Thus, it is not only the technology that is on trial but also its users (cf. Woolgar, 1991).

Based on these considerations, I assume that the introduction of LED lighting in cities involves the *testing* of the technology and requires the innovation to be *shown* to an audience. This raises more questions: Who are these audiences? Who are the presenters? And what exactly is tested and shown? In the following section I will explore three strands of literature.

2.2 Three ways of conceptualising LED projects in cities

In 1976, the authors of a pioneering study by the US Rand Corporation observed that 'in contrast to the vast literature on R&D, demonstration projects have received little attention as part of the process from basic research to commercial use' (W. S. Baer et al., 1976, p. iii). Apparently, little has changed since then. Although innovation research shows an increased interest in demand-side innovation (see appendix 10.1), user-producer interactions, recursive learning and niches for technological change,[14] implementation projects have so far received astonishingly little systematic attention. Chris Hendry and Paul Harborne claim that 'relatively little is still known about this ''uncertain middle'' phase' and how it contributes to 'complex, large-system innovation' (2010, p. 4507). In this section I will explore this research gap from different angles. First, I will give an overview of the policy-oriented and management-oriented research, as I call it (2.2.1). Subsequently, I will contrast these findings with social-scientific research that focuses on the implementation of innovations (2.2.2) and research on public experiments (2.2.3).

2.2.1 Technology trials and demonstrations

The first studies on implementation projects, or more precisely policy reports, were published in the 1970s in the USA. They coincided with an increase in state funded demonstration projects (W. S. Baer et al., 1976; Glennan, Hederman, Johnson, & Rettig, 1978; Myers, 1978). In the context of a liberal, non-interventionist political climate, the aim of this research was to assess the appropriateness and effectiveness of these subsidies (Lefevre, 1984).[15]

[14] Networks and systems of innovation are increasingly expanding beyond firm and market contexts—after a period of relative closure, and dominance by in-house R&D and Big Science (Freeman, 1995; Mowery, 1995). The opening-up is also reflected in management models (Chesbrough, Vanhaverbeke, & West, 2006) and researchers' interest in users as producers of innovation or competent partners (B.-Å. Lundvall, 1985; E. A. Von Hippel, 2005; E. Von Hippel & Katz, 2002) and in the rediscovery of demand side innovation policies(Edquist et al., 2000), together with user-centred 'living labs' under real-life conditions (Almirall et al., 2012; Bergvall-Kareborn & Stahlbrost, 2009; Eriksson, Niitamo, & Kulkki, 2005). The relevance of 'niches' for technological transition is also highlighted in multi-level perspectives (Geels & Schot, 2007; Hommels, Peters, & Bijker, 2007; Kemp et al., 1998).

[15] In the face of the energy crisis the state expanded its activities beyond traditional areas of activity like agriculture, health care, defense and nuclear power and began to sponsor civilian innovation, particularly energy-related technological innovation. As Stephen R. Lefevre observes, 'the fuel crisis made the exception the rule,' and demonstration projects were the favourite policy device (1984, p. 483). The 'traditional laissez faire attitude' gave way to federal 'technology forcing' (Michaelis, 1976).The 'essence of this attitude' was that the US government must not become a 'product advocacy lobbyist'and should not attempt 'to develop particular technologies when it has no direct procurement interest in the innovation itself (quoting Eads & Nelson, 1971; Lefevre, 1984, p. 483; Richard R Nelson, 1982; Richard R. Nelson & Langlois, 1983).

The 1976 Rand report[16] offers a functional, diffusion-oriented definition: Demonstration projects are successful if they provide 'new information to aid decision-making by potential adopters and other target audiences' and can reduce 'five kinds of uncertainty'—regarding the technology, cost, demand, institutional setting and externalities of an innovation (W. S. Baer et al., 1976, pp. 3-4). Based on this differentiation, the authors identify three interrelated indicators: *information success,* 'when all uncertainties are reduced to a point where a lack of information does not prevent adoption decisions'; *application success,* when 'the technology demonstrated works well in the local setting' and *diffusion success*, which is 'defined as the extent to which technology passes into general use…' (1976, pp. 4-5).[17] The report outlines a number of success factors that were further developed or challenged in later studies as I will briefly outline.

First, it is argued that timing matters and that test or demonstration projects should be designed with regard to the development stage of the technological innovation. The 1976 Rand report suggests that projects can accelerate diffusion, especially if technical problems have been solved beforehand. Accordingly, later studies distinguish between pilot projects, which aim to solve technological problems, and demonstration projects, which aim to reduce institutional and economic uncertainties (J. L. Smith, Gates, & Lee, 1978), or between projects in the experimental or 'take-off' phase of an innovation (Karlström & Sandén, 2004, p. 288). Myers understands *experimental technical demonstrations* as a form of applied research and *commercial demonstrations* as a diffusion factor (1978, p. 27). He also relates this distinction to different project designs, audiences and 'management postures' (see Table 2-1).

[16] The study was based on the analysis of 24, apparently most dissimilar case studies on publically funded projects and programmes in different industry sectors and with mixed outcomes. The cases vary in terms of project size and diffusion stage and with regard to the technologies and federal agencies involved. They were chosen from 41 programmes funded by 12 different federal US departments. Project characteristics include a) federal funding, b) direct stimulation of technological change in the civilian sector (no defense-activity spin-offs), c) significant private sector involvement (intended adopters or suppliers) (W. Baer et al., 1976; W. S. Baer et al., 1976, p. 2).

[17] The latter is also described as 'the 'pay-off' measure of success with information and application success as 'necessary but not sufficient conditions' (W. S. Baer et al., 1976, pp. 4-5).

	Technical demonstration (experiment) Tests feasibility	Commercial demonstration (example) Shows utility
Audience	- Sponsors	- Customers
Project design objectivities	- Low visibility - Quantitative control & evaluation - Simulated pertinent environment - Smallest scale to get information	- High visibility - Sufficient control for credibility - Full operational environment - Fullest scale to approximate reality -
Management	- Healthy scepticism	- Optimistic assurance
Observers	- Sponsors of innovation	- Potential adopters of innovation

Table 2-1: Demonstrations: Technical versus commercial (source: Myers 1978, p. 15).

These studies thus make a clear-cut distinction between testing and showing innovation: 'Testing the feasibility of technology when it has already been proved feasible is a waste of money, and a premature attempt to catch the public's eye may create disappointment and a bad reputation when it turns out that the technology is not ready for commercialisation' (Karlström & Sandén, 2004, p. 288). Yet this opposition is disputable.[18]

Stephen Lefevre argues that 'demonstrations are experiments' and that technical failure and delays should be accepted and expected because technical unknowns are inevitable in complex real-life situations (1984, p. 489). New technologies are not only tested or shown but also *reinvented* (Magill & Rogers, 1981). The supposedly linear sequence from testing to showing does not reflect reality and actual innovation practices.[19] Furthermore, project sponsors' definition of a project might not correspond with the actual experiences or interests of local project partners (Lefevre, 1984; Magill & Rogers, 1981). Experimental projects can be used for demonstrational purposes and vice versa. To James Brown and Chris Hendry 'it is evident' that implementation projects have 'multiple and even contradictory objectives, and that these may change over time…'(2009, pp. 2560-2561). They explicitly account for the messy reality by referring to 'DTs'—demonstration projects and experimental field trials as

[18] Another Rand report points out that the term 'demonstration' is itself ambiguous: Demonstration can relate to a technology and its advantages or indicate an awareness of political challenges (Glennan et al., 1978, p. v).[18]
[19] For instance, the authors of a 1978 study on the US photovoltaic industry report cases in which exemplary commercial production plants and experimental pilot plants were established simultaneously, before the innovation had been tested on a small scale (J. L. Smith et al., 1978, pp. 3-18). Furthermore, the relationship between small-scale and large-scale projects and their effects is not necessarily a linear one. Scaling-up might lead to different environmental effects (cf. Karlström & Sandén, 2004).

one unified research subject, argue that earlier characterisations 'appear rather limiting' and call for a 'clear and actionable definition' (cf. J. Brown & Hendry, 2009; Harborne & Hendry, 2009, p. 3593).[20]

In terms of *application success*, it is pointed out that success is more likely if the project partners are competent and are willing to share the financial risk (W. S. Baer et al., 1976). Magnus Karlström and Björn Sandén argue that public-private cooperation is crucial due to uncertainties and long payback times. Cooperation can not only reduce financial risks but also legitimise new technologies (2004, p. 287) This is in line with Lundvall's observation that asymmetric or even dysfunctional producer-innovator interactions make 'unsatisfactory innovation' more probable (B.-Å. Lundvall, 1985).[21] He further argues that strengthening the technology users' competence and influence 'might have dramatic effects upon the innovative capability of the economy' (B.-Å. Lundvall, 1985, p. 36).

Political visibility is considered detrimental to success. If projects are designed to be too large or too expensive they run the risk of becoming subject to external time pressures and political objectives (W. S. Baer et al., 1976).[22] In terms of project management, the political prominence and high costs of projects can tempt governmental officials to 'usurp' managerial power (Lefevre, 1984, p. 488). Political objectives can undermine project objectives, learning opportunities for innovators and users might be lost and the emerging user-producer network distorted. Another danger lies in highly visible projects that give the impression that a technology is 'ready-to-go' technology whereas, in fact, successful implementation depends on local adaptation and 'reinvention' (Magill & Rogers, 1981, p. 38), which brings us to the challenge of disseminating information.

[20] Harborne and Hendry further argue that government funding is 'in practice […] often indiscriminate between technology and market objectives' (Harborne & Hendry, 2009, p. 3586). Projects are not only ambiguous per se but also deliberately ambiguously denoted as somewhere between R&D and showcase by project funders. Meanwhile, engineers tend to differentiate on the basis of scale. Smaller projects are considered to be helpful in the field-trial phase and larger projects for testing market attractiveness.

[21] Drawing on four case studies, Lundvall describes how inequalities in the distribution of competences and the producers' blind pursuit of technological trajectories can result in unsatisfactory innovative solutions. The examples include cases of 'hyper-automation' and 'hyper-centralisation' which resonate with current cases of innovation in public lighting. While the industry is pushing 'smart' and 'intelligent' telemanagement solutions and contracting models, municipalities might actually benefit more in economic terms and in the long-term perspective if they remain in control of more conventional technology (B.-Å. Lundvall, 1985).

[22] Offering the example of Thomas A. Edison's small-scale implementations of electric lighting, Karlström and Sandén argue that projects are likely to be larger in size if the technology is more mature (cf. Harborne & Hendry, 2009; Karlström & Sandén, 2004, pp. 288-289).

Information success, that is the successful production and dissemination of information, is considered crucial for reducing uncertainty. It can be managed in a top-down manner, for example, by the funding agency and via media-based diffusion channels like professional journals (cf. Lefevre, 1984, p. 489), or horizontally, as occurred in the case of an urban 'call-a-drive' transportation system described by Kathleen Magill and Everett M. Rogers (Magill & Rogers, 1981). The authors show that urban innovators and potential adopters exchanged technical and administrative information directly and in a peer-to-peer manner, on the telephone or, even more effectively, during site visits (1981, p. 37). Interestingly, information flowed irrespective of whether a project was state-funded or not. Based on their analysis, Magill and Rogers propose a horizontal model of peer-to-peer diffusion.[23] The model applies to innovations that involve a high degree of adaption and 'change throughout the diffusion process, taking many forms as different adopters "re-invented" it to suit their local conditions' (1981, p. 39). In contrast, vertical top-down diffusion applies to innovations that function largely independently of their implementation environment.

In addition to that, Rogers argues that the *observability* of the implemented newness affects the dissemination of information (E. M. Rogers, 1995).[24] As diffusion research shows, projects that test and show *observable* technology are more effective in terms of diffusion (Hruschka & Rheinwald, 1965; Magill & Rogers, 1981). This raises questions regarding the observability of black-boxed but shining LED lighting.

Finally, *diffusion success* is linked to market creation and the formation of supply and value chains (Karlström & Sandén, 2004). Magill and Rogers argue that, in the case they describe, local implementations sent a signal to municipalities and local organisations that the transport issue was high up on the federal political agenda and that funding was available (1981, pp. 33-34). Similarly, Harborne and Hendry suggest that projects might foster 'advocacy coalitions' or 'signal an innovation to potential markets and stakeholders' (Harborne & Hendry, 2009, p. 3586). Thus, implementation projects can have effects beyond the local level as they show that an innovation has the potential to meet 'social needs' or solve 'socio-

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[23] Rogers further developed this insight in later editions of his seminal work on the 'diffusion of innovations' where he distinguishes between centralised and decentralised diffusion processes (cf. Nutley & Davies, 2000; 1995).

[24] According to Rogers, observability is one of the innovation characteristics that affect diffusion, together with compatibility, complexity, triability and its observability. In the context of publically visible LED installations, the latter aspect seems particularly important: '*Observability* is the degree to which the results of an innovation are visible to others. The easier it is for individuals to see the results of an innovation, the more likely they are to adopt it' (E. M. Rogers, 1995, p. 16).

technical problems' (Karlström & Sandén, 2004, p. 287). 'Early investment in technology demonstration and limited deployment can provide feedback to improve the technology and to learn about the institutional and policy adjustments and physical infrastructure needs for a new technology' (Norberg-Bohm, 2002, p. x). Demonstration projects are therefore 'popular, particularly among the specific constituencies they serve.' But they also 'carry a high potential for failure' (Lefevre, 1984, p. 489). This is not only due to project-related technical, administrative or political problems. Implementation projects also have their limits where institutional barriers to innovation like legal constraints or standardisation are concerned. In this case, 'their role is to identify them' (J. Brown & Hendry, 2009, p. 2562).

Summing up, this research on state-funded innovation projects draws attention to a number of aspects that are also relevant for my study. [25] First, it reveals that it is difficult to draw a clear-cut analytical distinction between technology trials and demonstrations from the innovation perspective, as it is not exactly clear what is shown and tested in these projects. Second, the above-mentioned studies suggest that it is important that project partners are competent, collaborate on eye-level and share the risk of implementing new technologies in real-life situations. We also learn that the politicisation of technology trials and demonstrations can be detrimental to application success. Third, the production of evidence and disemmination of information requires active management. It is easier when the innovation is observable and can take the form of horizontal top-down communication strategies or vertical peer-to-peer exchanges between early technology users and potential imitators.

Last but not least, these studies suggest that there is a research gap in the literature on innovation and technological transitions. According to the authors of the most recent studies on the subject 'there is a need for further, fine-grained analysis of the drivers, barriers, strategies, processes and practices involved…(Harborne & Hendry, 2009, p. 3594). Yet therein lies a methodological problem.[26] Most of the above-cited studies draw on secondary

[25] On this general analytical level, it seems irrelevant that most of the case studies were on state-funded projects while my focus is on mundane LED implementations, as it has been suggested that there is *no direct relationship* between the diffusion success and state support (Heald, Vogel, & Yin, 1977; cf. Magill & Rogers, 1981, pp. 25-26).

[26] Similarly, Karlström and Sandén stress that more effort should be made in assessing the design and effects of demonstrations on overall technological development, especially with regard to the production of either new technological knowledge or new information about the reliability, availability, maintenance and durability (RAMD) of new technologies in use. 'Other issues' that could be studied concern 'the full-scale potential and the transferability' of project-specific results'(Karlström & Sandén, 2004, p. 289).

data sources like project reports.[27] In the following section I will therefore turn to micro-analytical social-scientific research on 'innovation in the diffusion stage' (W. Bijker, 1992). These studies not only offer the desired 'fine-grained' analyses but also critical reflection on the notion of diffusion.

2.2.2 Configurations in socio-material networks

So far, we have learned very little about actual installation activities and site-specific circumstances. Technology users and their adaptation work were marginal in the above-mentioned literature. This is not surprising, since macro-perspectives focus on the overall development of innovative technologies and markets and are less interested in meticulous adaptation and implementation processes. This is particularly true for the above-outlined research on diffusion and market creation.

In diffusion models installation projects are considered adoption events—no matter how different they may be and notwithstanding the 'reinventions' they involve.[28] Therefore, they cannot account for local differences in the spread and usage of innovations (Rammert, 1993). To give an example, the LED luminaires that were installed in 2008 differ considerably from recent designs, which have more powerful LEDs and probably also different optical systems (see chapter 4). In diffusion statistics they are treated as identical events and aggregated in one data set. This eventually produces the S-shaped curve that describes the market penetration of LED luminaires in public lighting (E. M. Rogers, 1995). This perspective is therefore less useful for analysing the introduction of LED technology in cities.

[27] Harborne and Hendry, for instance, created a data base of projects in the USA, Japan and the EU 'over the last 20–25 years' (2009, p. 3581) in order to analyse how demonstration projects allowed manufacturers and potential customers 'to observe and trial' wind turbine innovations by facilitating learning—particularly 'learning by using' and 'learning by doing' (Kamp, Smits, & Andriesse, 2004). While their results show interesting differences between project designs on the level of innovation systems, they find—not surprisingly—that it is difficult to assess 'the value of learning […] without more detailed examination of [the] relationships among lead stake-holders, the level of project involvement, and the extent of information exchange in projects…'(Harborne & Hendry, 2009, p. 3595).

[28] Rogers defines reinvention 'as the degree to which an innovation is changed or modified by a user in the process of its adoption and implementation.' He points out that since the 1970s, scholars have found 'that a considerable degree of re-invention occurred for many innovations.' (p. 17) and also acknowledges that some innovations are more prone to reinvention than others. A hybrid seed corn, for instance, hardly allows for modification by farmers. He concludes that 'an innovation is not necessarily invariant during the process of its diffusion' and users do not necessarily play 'the passive role of just implementing a standard template of the new idea' (p. 17).

Instead, there is a vast body of social-scientific empirical studies that focus on the *implementation* of innovations and technology in use. The following studies exemplify this literature as they represent different ways of conceptualising 'innovation in the diffusion stage,' as Wiebe E. Bijker called it in his study on the invention of fluorescent lighting (1992).

In his paper Bijker rejects the idea of a linear innovation and diffusion process in the development of technological artefacts—according to him 'no stages can be distinguished'. Instead, he highlights the ongoing negotiations over product designs that continued to shape the technology even after the first fluorescent lamp was presented in 1938.[29] His study draws attention to the *'interpretative flexibility'* of technological artefacts, which is a result of the plurality of vested interests and professional views, in other words different 'technological frames'.[30] The fluorescent light tubes we know today are the result of these negotiations, and so are LED products. The study is an example of the so-called SCOT perspective (see footnote 2930). Bijker concludes that 'to understand the design process of technical artifacts, we should not restrict ourselves to the social groups of design-room engineers or laboratory personnel' (1992, p. 97).

A similar critique is presented by Werner Rammert in a comparative study on the implementation of telephone technology in France, Germany, Great Britain and the United States (1990; quoted from 1993, p. chapter 13). Rammert also rejects the notion of diffusion but for different reasons. Taking a macro-analytical socio-cultural perspective, he argues that the focus on 'diffusion factors' such as the availability of economic resources and political conditions, cannot explain the variety of early telephone implementations and uses on the national level. [31] Although telephone infrastructures were provided in all four states, the

[29] The first fluorescent product was advertised as 'tinted lighting', which was the first novelty. Incandescent light bulbs cannot shine in 'pastel tints' or 'pure colors'. 'Moreover, although their installation costs were higher, they were thirty to forty times more efficient than incandescent lamps for color lighting' (W. Bijker, 1992, p. 81). Soon, the manufacturer thought of producing a 'high-efficiency daylight fluorescent lamp' for general lighting purposes. Yet electricity utilities, who were important distributors of the electric light sources, were against the idea of an energy efficient light source, for obvious reasons. In this situation, the stakeholders negotiated a compromise and thereby reinvented the 'high-intensity daylight fluorescent lamp', which could integrate the engineers' professional 'science of seeing' and the energy utilities interest in selling energy. Although Bijkers insights about the social shaping of fluorescent lighting are highly instructive, his focus is on the design process inside firms while mine is on implementation activities in cities.

[30] 'Technological frames' are a key concept of the 'social construction of technology' approach, in short SCOT (W. E. Bijker et al., 1987; 1992). The concept stresses the duality of technological developments as both *envisioned and enacted* social facts and is very popular in the literature on science, technology and society (STS) and beyond (cf. Geels & Schot, 2007; Harborne & Hendry, 2009; Hommels, 2005b).

[31] For an account of early telephone installations and their uses in rural America see Ronald Kline (2003) who shows how farmers, especially wives and young people, challenged the technology providers' business models by using community lines for eavesdropping and collective music listening.

novelty was adopted much faster in the U.S. than in Europe. Furthermore, there was not just *one* telephone, but four different ways of implementing and using the innovation. Power relations and institutional arrangements between public and private stakeholders led to different infrastructural designs and implementations, which either promoted or slowed down the private adoption of telephones. The difference was most obvious in France and the USA. While in the USA, public and private actors negotiated and aligned their technological visions and roles dynamically, the centralist French did not provide such public-private *discursive arenas*. In addition to that, the *social acceptance* of the new communications device differed in line with the respective national cultures. In France, the state-controlled, 'monological' concept of telephone communication also reflected the rigidity of that country's social hierarchies and habitus. In the USA, the dialogical technological framing corresponded to an open and more egalitarian communication culture. Rammert concludes that *social* innovations are needed to complete and culturally appropriate *technological* innovations (1993, p. 264). As we will see, different discursive arenas can also be found in Lyon and Berlin and the different *communications cultures* in France and the USA bear some resemblance to the different 'lighting cultures' and varieties in the social acceptance of light colours and light levels in Europe.

A third micro-analytical perspective is proposed by the proponents of actor-network theory (ANT) (cf. Akrich, Callon, & Latour, 2006; Callon, 1986a; Latour, 1983). The ANT approach replaces the diffusion model with a 'model of *interessement*' (Akrich et al., 2002a; Akrich et al., 2002b). Success in innovation is not measured in terms of market breakthroughs or diffusion rates. Instead, success is conceptualised in terms of network formation: It depends on the innovators or the '*spokesperson's'* capacity to arouse *interest* in an innovation and to mobilise new allies, including people and things. To innovate thus means to engage all *relevant actors and artefacts* in a socio-material network that will eventually stabilise the innovation. In the process, the existing world is transformed and so is the innovation: 'To adopt an innovation is to adapt it (Akrich et al., 2002b, p. 209). Thomas A. Edison' success in introducing the incandescent light bulb along with electricity infrastructures is presented as an exemplary case (cf. Bazerman, 1999; Hargadon & Douglas, 2001; Thomas P. Hughes, 1983, 1989).

The ANT model can be used to describe innovation *processes* in different situations and on different scales.[32] Its strengths lies in describing how heterogeneous actors *and things*, such as innovators, technology and urban users, come together. While most ANT case studies offer 'fine-grained' descriptive accounts of individual innovation processes, the following study shows that the model can also be applied for comparative studies.

In their case study, Mangematin and Michel Callon (1995) describe the implementation of two competing urban traffic information system for cities—an 'open' system and a 'closed' proprietary technology. Although both information systems were designed to fulfil the same function, namely avoiding urban congestion and reducing air pollution, they targeted very different populations of technology users. The closed system was made for municipalities who had to be convinced or made 'interested' first. Testing it in limited areas in Berlin and London increased its legitimacy and raised media attention. In the case of the open system, the commercialisation network was already *inbuilt* since the technology was integrated in vehicles and was thus not operated by municipalities but by the automotive company that was already part of the development team. Car drivers were automatically involved when they bought a vehicle (1995, p. 450). In this situation, the builders of the closed system developed a hybrid version combining elements of both systems. The hybrid system was tested in Paris. The authors argue that gaining the identification and 'interessement' of appropriate first users is a strategically crucial success factor.[33] 'London and Paris […] are two symbolic cities capable of swaying the choice of all those European conurbations who regard their own traffic problems as similar to those of the French and British capitals' (1995, p. 453). They conclude that the success of one competing system over the other depends on whether its first users are '*representative of established social networks'* (1995, pp. 456, my emphasis). Thus, we might ask in what sense Lyon's or Berlin's LED lighting can be representative for other European cities.

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[32] Another famous example is the 'pasteurisation of France'. Bruno Latour focuses on a field trial in the course of which the microbiologist and chemist Louis Pasteur tested and publically demonstrated his newly developed vaccination method against anthrax on sheep. Latour describes the trial as a 'staging' because 'it is the public showing of what has been rehearsed many times before in his laboratory'—a repetition of laboratory trials in front of media and audiences (1983, p. 151). At the same time, the demonstration transforms society by introducing a new entity that was previously unknown: Pasteur actively modified the society of his time by introducing a new actor, the microbe (Latour, 1983, p. 156). Pasteur's innovation success lies in the successful translation of the outside world into the laboratory and then back again, establishing equivalent relationships across inside/outside boundaries and different scales (1983, p. 163).

[33] The authors show that the 'interessement' of the first urban users is strategically crucial in terms of producing 'lock-in' effects and 'increasing returns to adoption' (IRA) (cf. Arthur, 1989). The study highlights that technological 'lock-in' or 'irreversibility' is achieved through network formation, which starts very early in the technological design process but does not end with the implementation. They also argue that standardisation is only one strategy for achieving 'lock-in' effects and IRA (cf. Blind, 2008).

The interessement model is also known under the name of the 'sociology of translation' (Akrich et al., 2006; Callon, 1987).[34] It offers an analytical tool for describing innovation or installation processes in an 'agnostic' way, which means that the researcher pretends s/he does not know whether the interessement will be successful in the end or whether the emerging network will dissolve again (cf. Latour, 1996a).[35] After all, conflicting views and incompatibilities are rather common in innovation processes and alliances are fragile while the newly formed relationships in the socio-material network have not been black-boxed or routinised. The question is thus how newly formed or forged relationships can be stabilised or in other words 'how a few people gain strength and go inside some places to modify other places and the life of the multitudes' (1983, p. 163).[36]

The stabilisation of relationships is conceptualised in different ways. Interactions between actors and artefacts play an important stabilising role. Callon refers to 'interessement devices', for instance images that depict complicated facts in an obvious and visually appealing manner (Callon, 1986b, p. 209). Madeleine Akrich describes the 'scripts' in technological artefacts, that is, inscribed usages.[37] Antoine Hennion describes how repeated practice or training can stabilise the relationship between an 'amateur' and the object of his interest in the form of embodiments, for instance a refined 'taste' for music or wine (2001, 2004). Hennion's pragmatic research resonates with the more structural concepts of

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[34] The ANT model describes the introduction of innovations as a *process* of 'translations'. To translate means to create new relationships by mobilising and 'displacing' people and things. It also means 'to express in one's own language what others say and want […] it is to establish oneself as a spokesman' (Callon, 1986b, p. 223). Spokespeople are successful if they manage to understand and *represent* all relevant actors and artefacts in the innovation process. If they do not feel their objectives represented in the novelty, municipalities will not introduce a new traffic information system or LED luminaire. Similarly, the innovation will not have a chance if its material components are incompatible with existing urban infrastructures. The 'art of interessement' thus means to identify first *who and what is relevant* and then *enrol* these actors or artefacts in the innovation activity. 'At the end of the process, if it is successful, only voices speaking in unison will be heard' (Callon, 1986b, p. 223). In his famous case study on the scallops and fishermen of St Brieuc Bay, Callon distinguishes four elements or 'moments' (Callon, 1986b). Roles are defined and identities fixed in a process of 'problematization', 'interessement', 'enrolment' and 'mobilisation' (ibid). The distinction is analytic in character and does not imply a chronological order or sequenciality of the four moments of translation.

[35] Callon describes this as 'dissidence' or 'betrayal' (Callon, 1986b, p. 219).

[36] The creation of networks does not happen without force. Latour describes the innovator's art of interessement in terms of Machiavellian power politics or 'Realpolitik' as it creates new facts. 'Latour's view on the politics of innovations is explicitly Machiavellian', write Nahuis and van Lente (2008: 566) with 'domination as a matter of enlarging and unifying networks.' The 'Realpolitik', the strategies and tactics of successful innovators and their conditions and limitations can be analysed 'just like Machiavelli analyzed the successful paths to power.' Callon introduces his 'Sociology of Translation' with the words: 'This paper outlines a new approach to the study of power.' (Callon, 1986b). However, since ANT rejects the idea of power *structures* they cannot explain why some actors can act as spokespeople and excert power over others (cf. Hård, 1993).

[37] However, compared to the notion of 'user configurations', the notion of scripts leaves more room for interpretations or 'de-scripting' by users (Akrich, 1998; Akrich & Latour, 1992). According to Nelly Oudshoorn and Trevor Pinch the 'script approach makes users more visible as active participants in technological development' (2003, p. 10).

‘professional vision’ (Goodwin, 1994), that is, professional ways of seeing and categorising things. Nortje Marres focuses on socio-technological ‘engagement devices’, not in order to explain innovation but to highlight the political dimension of socio-material interactions.

Marres describes ‘green living experiments’, that is, ‘intimised’ forms of public experiments in the course of which individuals introduce a new technology in their homes in order to measure their carbon footprint, and then report their progress in ‘green’ or ‘carbon blogs’ (2009, p. 121). Marres argues that the introduction of electricity meters in private homes and the users’ measuring and reporting activities *engage* individuals in societal change. But instead of participating in political demonstrations (cf.Barry, 2001) or institutionalisation processes, the participants in private ‘green living experiments’ participate *materially*. By providing specifically designed ‘engagement devices’, in this case electricity meters, users’ ‘green living experiments can be seen to publicize the process of reconfiguring relations’(Marres, 2009, p. 127). In other words, by using the new technology, the individual users transform their homes into sites of climate change mitigation policies. Marres describes this world-shaping *ontological* practice as ‘material participation’ (Marres, 2012).

Looking at innovation from the ANT perspectives thus draws attention to the transformation of existing socio-material networks into something new by means of interessement and ‘displacement’. New technologies become part of the existing world—they become stable and irreversible—if actors and things *move* and *make space* for them in their existing world. Accordingly, John Law describes ANT as an approach that explores the *configuration and reconfiguration of relations* and enactments (Law, 2004, p. 157). Callon refers to network configurations as analytical constructs, suggesting that this might be a way of comparing their differences (Callon, Cohendet, & Curien, 1999). In this sense, ‘configurations’ describe those relationships in a network that are routinely or frequently enacted and therefore seem more stable. While ANT network configurations include actors and artefacts, the concept of configurations can also be widened to also include immaterial facts such as cultures and imaginaries (cf. Hutter et al., 2010; Suchman, 2012).

Accordingly, my research unit, the ‘Cultural Sources of Newness’ unit at the WZB, conceptualised ‘cultural configurations’ as an ‘analytical construct’ that allows us to explore the socio-material and imaginary situations in which newness occurs:

> ‘This construct makes patterns of interaction identifiable in time and space in that it records observable concentrations of interaction and communication processes. The notion of cultural configurations enables situative descriptions of cultures, for example in cities, networks, or projects’ (Hutter et al., 2010, p. 13).[38]

Lucy Suchman suggests that the ‘trope of configuration’ draws particular attention ‘to the entanglement of *imaginaries and artefacts* that comprise technological projects’ and join them together (Suchman, 2012, pp. 356, my emphasis). She outlines two broad uses of the term configurations. First, it delineates ‘the composition and bounds of an object of analysis.’ As such configuring can be understood as the *basic operation* that brings objects into existence. Second, the trope draws attention ‘to the ways in which technologies materialize cultural imaginaries, just as imaginaries narrate the significance of technical artefacts’ (Suchman, 2012, p. 347). As such, configuration accounts for sense-making activities that are not only reflected in language but also in visual representation, in short imaginaries.[39]

Against this backdrop, we can conclude that the ANT approach is very useful as an analytic tool for describing *network formation processes* but has its limits when it comes to analysing *mutable configurations* in which innovations become part of our familiar worlds. While ANT methodology is well-suited to *describing* the social and especially material adaptation of LED lighting in urban spaces and allows for ‘fine-grained’ analyses of innovation projects (see also chapter 3), it seems too radical to *explain* differences in urban LED configurations.

This radicalism results from its ‘flat’ and ‘symmetrical’ analytic approach. In other words, ANT rejects the idea of multiple levels of analysis or underlying structures and promotes a perspective that analytically treats human and non-human actors in the same ‘symmetrical’ way (Callon, 1986b). This perspective thus privileges observing and documenting actual interaction and material facts over analysing ‘virtual attractors’ (Farías, 2014) or the above-

[38] As an analytic device, the concept has the advantage that it does not hide the configuring role of the researcher. Deploying the device for technology studies implies a double move: a ‘joining together’ of material and semiotic practices, of matters and meanings that delineate the ‘figure’ on the one hand, and its reflexive ‘unpacking’—out of the ‘black box’ on the other. ‘Unpacking’ thus means trying or even deconstructing the ‘naturalised’ links between the figure and its contexts (cf. Suchman, 2012).

[39] Suchman refers to ‘imaginaries’ as a ‘term of art’ that describes ‘how we imagine the world is shaped not only by our individual experiences but also by the specific cultural and historical resources that are available to us’ (Suchman & Bishop, 2000, p. 332). She refers to George E. Marcus’s highlighting of the ‘immediate association’ of the term with visual artefacts and visualisation practices on the one hand and the ‘visionary, innovative, imagination, on the other—an orientation to imagining futures and the fantastic’ (Marcus, 1995b, p. 3). This visual orientation suits my analysis of a new lighting technology which is promoted for its twofold aesthetic appeal, namely as a design object or piece of street furniture that is visible by day and a source of light which (trans)forms nocturnal urban images (see chapter 3).

mentioned technological frames and institutional settings (cf. W. Bijker & Law, 1992; Rammert, 1993).

Accordingly, socio-material networks do not signify the same thing as heterogeneous 'networks of innovation' (Kowol & Krohn, 1995; Rammert, 1997a; Sorensen & Levold, 1992). The latter refers to a structural principle that is complementary to organisations and markets and facilitates exchange between heterogeneous actors across the boundaries of their organisations (cf. Callon et al., 1999). In the ANT terminology, 'network' refers to *relationships* between heterogeneous entities, human *and non-human*.[40] In contrast to the more common structural notion of networks, ANT *does not specify* the quality of network links but only states that they exist. Flat or symmetrical, it refrains from specifying or speculating *why* actors and things act differently.

In this respect, Laurent Thévenot's pragmatic concept of '*investments in form'* and plural '*modes of engagements'* (Thévenot, 2007) seems methodologically close enough to add some structural 'depths' to the 'flat' ANT approach: The concept suggests that stabilisation can be achieved through *investments in form* (Thévenot, 1984). 'Such investments imply costly construction operations' (Thévenot, 2007, p. 513). In return, they facilitate social coordination and the stabilisation of relationships, *materially* and over *time* and *space*. As a result, different formats, for instance standards, statistics or trained bodies, may be more or less suited to stabilising relationships over time and distances. They also *engage* people differently. Here, Thévenot distinguishes between plan-oriented, public, exploratory and familiar engagement. Such engagements can be understood as a qualified version of ANT network relations.

Engagement in a plan reflects the capacity to 'project oneself in the future'. This mode underlines an individual's autonomy to act and pursue strategies in changing, complex social situations (Thévenot, 2007, p. 417). *Public engagements* make reference to a common good. By justifying their action in public, individuals evoke shared moral orders or 'worlds of worth', for instance the efficiency-oriented industrial world or the 'green' world of justification that emerged with a growing awareness of climate change (Boltanski & Thévenot, 2006; Thévenot, 2002). *Exploratory engagement* is neither planned nor justified in

[40] Callon (1999) differentiates as follows: a) the ANT 'proto-notion' of networks as socio-material formations and b) a hybrid form of organisation and specific mode of coordination that differs from organizational hierarchies and markets. According to Callon, the second notion allows us to study complex systems and the border-crossing alchemy of innovation and the interplay of scientific laboratories, industrial firms and policy-makers.The proto-notion, in contrast, serves to analyse the emergent event of network formation, in other words, innovation in the making (1999, pp. 13-14, my translation).

public. It implies a 'close relation of a person to his or her environment which is situated below the public recognition of an innovation' (Auray, 2007; Thévenot, 2011, p. 51). Last but not least, *familiar engagements* maintain 'a personalized, localized good: feeling at ease.' This experience of well-being is analytically difficult to grasp as it depends on how a person has familiarized her/himself with 'a milieu shaped by continued use' (Thévenot, 2007, p. 416). However, it is particularly relevant with regard to implementation projects. On the one hand, Thévenot stresses the tension between familiar and exploratory engagement. On the other hand, every installation of new public lights has the potential to change familiar worlds where it 'must be given meaning and evaluated', as we have seen (Nowotny, 2008). This brings me to my last perspective. This looks at 'public experiments', which are always also public engagements (cf. Marres, 2009; Shapin, Schaffer, & Hobbes, 1985).

2.2.3 Public experiments

Another way of looking at LED projects in cities is to conceptualise them as 'public experiments'. This conceptualisation draws attention to epistemic problems of evidence production in real-life situations.[41] In other words, it allows me to specify the circumstances under which innovating in public can transform uncertainty into certainty.

There is an undiminished interest in public experiments in both theory and praxis. As Bas van Heur and Andrew Karvonen point out, 'experiments' are *en vogue*.[42] Bruno Latour characterises social change as 'collective experimentation' (2009), Ulrich Beck speaks of 'global experiments' (1995). Fabian Muniesa and Michel Callon argue that 'the word "experiment" has become pervasive in contemporary economic life' (2007, p. 163).[43] 'Urban laboratories' and 'living labs' are mushrooming throughout the European Union in order to foster open innovation and co-creation practices.[44]

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[41] 'In contrast to objectivity and truth', evidence can be understood as uncontested and therefore 'unquestionable certainty' (unhintergehbare Gewissheit, Rüb & Straßheim, 2012, p. 380)

[42] This also became clear in a recent workshop 'experimental society' (February 2014) organised by Stefan Böschen, Matthias Groß and Wolfgang Krohn at the Karlsruhe Institute of Technology (KIT) https://www.itas.kit.edu/downloads/ta-kalender_20131208_cfp.pdf, last access 2014-07-15.

[43] Muniesa and Callon prefer 'in vivo' over 'real scale' or 'in situ' experiments, as the 'biomedical metaphor' captures that this 'experimental configuration is not only about widening the scale of the experimental site' but that the latter also 'becomes more uncertain' (Muniesa & Callon, 2007, p. 178). Their example of an *in vivo experiment* is the introduction of a new financial market trading system.

[44] The European Network of Living Labs (ENoLL) was founded in 2006 and encompasses 340 accepted living labs (ENoLL, 2014). 'Living labs' are promoted as a way of public testing under real-life conditions.44 'Living labs are situated in the fertile, middle ground of user involvement'and 'driven by two main ideas', namely the

‘These ideas are thought-provoking on a general level, but the terminology of experimentation is frequently evacuated of meaning and becomes frustratingly imprecise when applied to empirical research’ (Karvonen & van Heur, 2014, p. 5).

I will therefore start with a brief overview of the sociological research on public experimentalism in the context of innovation and then focus more closely on its socio-spatial implications.

The concept of *‘real-life experiments’* (Weingart & Krohn, 1986) draws attention to the risks that scientific research and technological development outside the laboratory imposes on the ‘experimental society’ *(Experimentalgesellschaft)* (Herbold, Krohn, & Weyer, 1991). Research on that subject[45] critically explores the ‘tendency to extend research processes and their related risks beyond the limits of the laboratory or other such institution, and directly into the wider society’ (Krohn & Weyer, 1994, p. 173). Real-life experiments are performed when innovations can only be assessed in *in vivo* because they are too complex to be tested in laboratories or test sites. Examples include waste disposal technology, genetic engineering or complex IT systems (cf. Muniesa & Callon, 2007; van den Daele & Krohn, 1998). They can also occur when catastrophes, wars or fatal technological failures are experimentalised, as in the case of the nuclear catastrophe in Chernobyl (Krohn, 2007). Yet real-life experimenting can also be much less dramatic.

Most research on real-life experiments is concerned with *scientific* experimental practice, in other words, the question of how scientists can play an active part in technological development and heterogeneous ‘innovation networks’ (cf. Kowol & Krohn, 1995; Rammert, 1997a) but without compromising their role or the principles of good scientific practice (van den Daele & Krohn, 1998).[46] It is suggested that the ‘significance of science in innovation is not the contribution of approved knowledge, but rather the import of experimental strategies in the design process, the operation, and the monitoring of a new technology’ (van den Daele

involvement of ‘users as co-creators on equal grounds’ and ‘experimentation in real-world settings’ (Almirall et al., 2012, p. 12). Thus, they are ‘both an innovation milieu and an innovation approach’ (Bergvall-Kareborn & Stahlbrost, 2009, p. 356). As public sites for co-creation, exploration, experimentation and evaluation they are meant to facilitate the innovation as an answer to social needs. The approach seems particularly appropriate ‘where the fit of a particular technology or set of technologies to a precise context is more significant’ or ‘unique to a given set of users’ (Almirall et al., 2012, p. 18).

45 ‘Real-life experiments’ are also referred to as ‘social’, ‘implicit’ or open experiments (Groß et al., 2005; Herbold et al., 1991; Krohn, 2007).

46 Wolfgang van den Daele and Wolfgang Krohn argue that ‘to understand how science can be both distinct from and related to politics and economy is still an issue and will be all the more important the more science becomes an agent of social change in processes of modernization’ (van den Daele & Krohn, 1998).

& Krohn, 1998). It seems that the uncontrollable real-life laboratory 'calls for a science that is robust enough via recursive learning processes to "listen" to both different interest constellations and unexpected natural changes' (Gross & Hoffmann-Riem, 2005, p. 279). Thus, the challenge of producing knowledge in the real world lies in absorbing and compensating for the lack of control through the institutionalised 'recursive design of the research process […] for instance: frequent public participation or the openness to surprises… (Gross & Hoffmann-Riem, 2005, p. 280). The scientific production of falsifiable knowledge itself becomes an experimental process, in the course of which the tension between knowledge and non-knowledge is relaxed and the boundary between science and non-science shifts (Böschen, 2013b; Gross & Hoffmann-Riem, 2005; van den Daele & Krohn, 1998).

Similarly, the notion of '*urban laboratories'* draws attention to public experimenting as part of urban change, in other words experimental modes of urban governance (Evans & Karvonen, 2014; Karvonen & van Heur, 2014). 'Urban laboratories bring politics and innovation together and might therefore "relocate innovation" reflexively', write Andrew Karvonen and Bas van Heur.[47] James Evans and Karvonen describe urban laboratories as a type of experimental governance, in line with policy experiments and sheltered niches as they are described in the Dutch transition literature (Geels, 2002; Geels & Schot, 2007; Kemp et al., 1998).[48] 'Empirical evidence reveals that urban laboratories provide governance by other means through an explicit emphasis on scientific knowledge production' (Evans & Karvonen, 2014, p. 415).

The notion of 'urban laboratories' is used by both urban innovators and researchers. As an empirical concept, it can be part of a 'rhetorical strategy' *or* signify a 'genuine attempt to cultivate emancipatory forms of change' (ibid). According to the authors we no longer need to ask if the city can be a laboratory.[49] 'Park and the Chicago school have discussed and shown it already.' Instead, the question is 'what can we see that we otherwise would not see?' using

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[47] 'These spaces of innovation and change provide a designated space for experimentation where new ideas can be designed, implemented, measured and, if successful, scaled up and transferred to other locales. […] these constructed spaces of innovation provide a fascinating lens through which to critique and reflect on the future of cities.' (Karvonen & van Heur, 2014, p. 11). As such, they are 'part of a wider discursive field that includes ideas of Mode 2 science, triple helix formations, engaged research, service learning, transdisciplinarity, living laboratories, applied innovation and the co-production of knowledge…' (Karvonen & van Heur, 2014, p. 2).

[48] For my project, this multi-level perspective on niche technology implementations less relevant as it does not capture the urban scale of technological transitions. For a corresponding critique see Mike Hodson and Simon Marvin (2009, 2010).

[49] Karvonen and van Heur stress the methodological implication of the pragmatist Chicago school approach, which suggests that knowledge is produced 'through the development of concrete projects aimed at experimentally testing possible solutions to social problems' (Karvonen & van Heur, 2014, p. 7).

this 'this new-old terminology' of the urban lab (Karvonen & van Heur, 2014, p. 7). They give three answers. First, urban laboratories differ from other sites of innovation as they 'embrace' uncertainty and contingency. Like other real world experiments they are 'founded on the idea that we are compelled to act despite vast uncertainties and gaps in knowledge' (cf. Callon, Lascoumes, & Barthe, 2009; Karvonen, Evans, & van Heur, 2014, p. 5). The second 'achievement' of urban laboratories is an explicit *focus on change* that differentiates them from the ubiquitous and contingent transformation processes that happen in cities all the time. The third achievement is *situatedness*: Urban laboratories are actively created, designed and made visible by experimenters. The knowledge they produce derives its legitimacy from its embeddedness in actual places and real-life situations (cf. Groß et al., 2005; Krohn & Weyer, 1994). The experimenters' situated practice is political as they deliberately choose and decide what evidence they produce and where (Evans & Karvonen, 2014, p. 425).

We can conclude that the 'real-life experiment' and 'urban laboratory' both focus on scientific knowledge production in messy situations. While 'urban laboratories' are closer related to urban governance and highlight the *socio-material* dimension of innovation, the concept of real-life experiments is analytically wider and highlights the risks and problems of scientific evidence production outside laboratories and research institutions, where scientific truth claims are exposed to the reality of concrete situations and *heterogeneous audiences*. Since this social and spatial dimension of innovating in public is also highly relevant in my project, I will explore it in more detail here.

Scientific knowledge production takes place in physical and social space: on the one side, there is 'immediate experience; on the other, reliance on authority and trust' (Ophir & Shapin, 1991, p. 9).[50] This is also true for the evidence produced in the course of technology trials or demonstrations. 'Social life as a whole and the social procedures used to make knowledge are spatially organized', writes the science historian Steven Shapin (1988, p. 374).

The inherently social and spatial dimension of testing and showing and its cultural contingency becomes particularly clear when we adopt a historical perspective (cf. Shapin et

[50] Adi Ophir and Steven Shapin further argue: 'Within knowledge-making sites, epistemological and disciplinary distinctions are related to spatial arrangements that differentiate degrees of visibility, directness of access to objects of research, facility of movement between workplaces, and density of interaction among persons occupying different positions at different locations' (1991, p. 9).

al., 1985).[51] In the mid-17th century, new spaces of knowledge production emerged in Europe, particularly in England, with the emergence of empiricist modern science.[52] As Shapin points out, '*trying* was an activity that in practice occurred within relatively *private* spaces, whereas *showing and discoursing* were events in relatively *public* space' (Shapin, 1988, pp. 400, my emphasis). The 'routine and rigorous' distinction was also reflected in the language of early-modern empiricists: 'In mid to late seventeenth-century England there was a linguistic distinction […] between "trying" an experiment, "showing" it, and "discoursing" upon it' (1988, p. 399).

Demonstration spaces were 'disciplined' settings marked by spatial conditions and social conventions. Venues ranged from coffeehouses to apothecary's shops. Yet the most important places were the private residences of gentlemen, who themselves played a crucial role as trustworthy witnesses and supposedly disinterested and free observers. Thus, their presence ensured that experimental knowledge was reliable and objective. 'What underwrote assent to knowledge claims was the word of a gentleman, the conventions regulating access to a gentleman's house, and the social relations within it' (Shapin, 1988, p. 404).

We see that scientific evidence production in early-modern times involved testing or showing and discoursing as spatially separated practices. Testing, which implied the risk of error and the possibility of creating uncertainties or new knowledge, was performed 'in private', while evidence was presented and discussed in public, with the aim of generating social acceptance of new facts. Public demonstrations of experimental evidence were rehearsed and carefully staged, since the presenter relied on observers in order to have his new facts approved.[53] Thus, early scientific experiments were 'public' in the sense that early-modern scientists showed their new facts in front of *heterogeneous* audiences, including fellow researchers and gentlemanly observers with social authority.[54] They were *placed* in spaces—houses, cafés or

[51] Historians and sociologists of science have long studied social places of knowledge (MacDonald, 1998; Stafford, 1994; Yates, 1992).
[52] Solitary knowledge production became problematic. The British natural philosopher Robert Boyle and his Royal Society colleagues argued that the legitimacy of experimental knowledge 'depended upon a public presence at some crucial stage or stages of knowledge making.' This 'crucial stage' was the showing of the experiment. The acknowledgment of authentic experimental knowledge, which was produced in private spaces, 'involved its transit to and through a public space' (Shapin, 1988, p. 384).
[53] After all, at the time there were no scientific peer-review systems in place.
[54] Shapin concludes that the 'contrast with more modern patterns is evident.' Today there is an 'almost absolute' separation between places of residence and places of knowledge production which 'means that a new privacy surrounds the making of knowledge whose status as open and public is often insisted upon. The implications of this disjunction are both obvious and enormously consequential. Public assent to scientific claims is no longer based upon public familiarity with the phenomena or upon public acquaintance with those who make the claims. We now believe scientists not because we know them, and not because of our direct experience of their work.

shops—with a highly socially stratified 'publicness' and hence manageable visibility—which raises the question of how urban public spaces function as situations for staging innovation. The sociology of scientific knowledge can provide some answers in this respect.

The spatial dimension of knowledge production is most explicit in Thomas F. Gieryn's work. He draws attention to 'the paradox of place and truth' (Gieryn, 2002, p. 113). Although scientific truth involves claims to general validity and although its credibility is diminished by situatedness, 'they originate at some place'. In fact, places are constitutive for the production of transferable evidence:

> '[T]he place of provenance itself enables the transit of some claims from merely local knowledge to truth believed by many all around. The passage from place-saturated contingent claims to place-less transcendent truths is achieved through the geographic, architectural and rhetorical construction of a "truth-spot" (i.e., the place of provenance)' (Gieryn, 2002, p. 113).

He distinguishes between three kinds of truth-spots.[55] The first is *the field*, the workplace of ethnographers. The field is a 'place celebrated' that is constructed by the scientific author 'through skilful rhetoric' (Gieryn, 2002, p. 118) as an unspoiled, authentic setting in which s/he observes nature or society *in vivo* without intervening and from the perspective of an immersed stranger (cf. Simmel, 1950). The scientific knower presents her/his relationship with the place in a way that enhances insight, objectivity, accuracy and trust (Gieryn, 2002, p. 118). The second truth-spot is *the farm*, a 'place of display, demonstration and performance: Knowledge is made credible and disseminated as it is shown to visitors—see: it works!' (Gieryn, 2002, p. 123). Gieryn's example is a real farm, where agricultural knowledge is shared with 'visiting publics' in the place where it is applied in practice. The architectural arrangement and design of the location turn truth claims into first-hand experiences as they 'render ideas about science and about nature into tangible, believable forms ready for take-away' (Gieryn, 2002, p. 124). The third truth-spot is *the laboratory*. It is, historically speaking, also the youngest one. The lab is 'a place denied'. Its architecture, equipment and design are erased from the research papers that leave the lab space. Truth claims derive their authority from the assumption that lab conditions are 'generic' and comply with the

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Instead, we believe them because of their visible display of the emblems of recognized expertise and because their claims are vouched for by other experts we do not know' (Shapin, 1988, p. 404).

[55] Truth-spots are 'places' in the sense that 'they are not just a point in the universe, but also and irreducibly: (1) the material stuff agglomerated there, both natural and human-built; and (2) cultural interpretations and narrations (more or less explicit) that give meaning to the spot' (Gieryn, 2006, p. 29).

cleanroom standards of their particular scientific discipline. This standardisation has practical implications:

> '[It] enables scientists to presume that research in other labs involves people who are like them and who are behaving as they do […] Indeed, to bring up such presumably standardized infrastructural elements of a lab risks its conversion from a truth-spot to an epistemically "stigmatized place"' (Gieryn, 2002, p. 128; quoting Hayden, 2001).

The closed arrangements of laboratories and their homogeneous, standardised observation practices, which are also performed by scientists with the same disciplinary backgrounds (cf. Collins, 1985), make them effective as sites of uncontested knowledge production. Gieryn is not the first to highlight these socio-material particularities of laboratories (cf. Knorr-Cetina, 1995; Latour & Woolgar, 1986).[56] So-called laboratory studies show in detail how scientists apply specialised equipment according to the rules of their 'epistemic culture' (Knorr-Cetina, 1999) in order to make experimental results visible and unambiguous.[57] The sociologist Trevor Pinch describes the 'radical transformation' that has resulted from these social-constructivist and pragmatist perspectives on science as follows:

> 'Experiment, rather than being seen as the means to verify, confirm, or refute scientific theories, or as providing the observation statements upon which correspondence theories of truth may be built, is treated as a process of argumentation and persuasion: Human agency in the production of agreement about the content of nature has become the principle locus of inquiry' (Pinch, 1993, p. 29).

What laboratory studies also highlight is that the expert's power of persuasion and authority originates, at least in part, in the *socio-material arrangement* of his/her laboratory. 'The layman is awed by the laboratory set-up' and 'left without power, that is, without resource to contest, to reopen the black boxes, to generate new objects, to dispute the spokesman's authority' (Latour, 1987, p. 93).

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56 For an explanation of how experiments and laboratories relate as a topic of science studies see Karin Knorr Cetina (1992).

57 For instance, Bruno Latour's and Steve Woolgar's ethnomethodological study describes in detail how natural scientists interact in the carefully arranged material settings of their laboratories and how they apply instruments and 'inscription devices' to construct scientific facts (Latour & Woolgar, 1986). Laboratory set-ups and equipment allow scientists to produce *inscribed visual evidence* that can travel beyond the confined space of the laboratory. 'Going from the [published] paper to the laboratory is going from an array of rhetorical resources to a set of new resources devised in such a way as to provide the literature with its most powerful tool: the visual display' (Latour, 1987, p. 67). Karin Knorr-Cetina and colleagues (1988) show that the scientific laboratory is a place where 'the social' is not suspended but condensed in socio-material practices of knowledge production (Karin Knorr Cetina et al., 1988, p. 87). Laboratory experiments are highly routinised and embedded in the 'epistemic cultures' of the science communities that work in that place (Knorr-Cetina, 2007).

Coming back to LED projects in cities we see ourselves confronted with a problem. The unrestrained, messy *urban spaces* could not differ more from the controlled, clean, private and 'denied' laboratory space. Although the public spaces of cities are also socially stratified— in culturally contingent ways (cf. Sennett, 1969)—they are still densely populated by potential observers from heterogeneous social, personal and professional backgrounds (cf. Wirth, 1938). In contrast to 'the farm', urban architectural arrangements are not built for just one purpose and are therefore tricky as sites for public display. As a 'field' they are not only studied and 'celebrated' by one expert researcher but are subject to multiple and potentially diverging representations. Gieryn addresses this problem by outlining the difference between the 'essentialist' urban sociology of the Chicago School in the 1930s and their notion of the 'urban laboratory', from which the 'field' truth-spot is derived (T. V. Smith & White, 1929), and the 'postmodern' positions of the Los Angeles school in the 1980s. While the Chicago School presented Chicago as a *typical* example, the latter refrain from making essentialist truth claims and did not privilege scientific knowledge production over other ways of making sense of 'The City' (1996).[58] Instead, the Los Angeles School 'invites its audiences to co-construct the place' (Gieryn, 2006, p. 26). Los Angeles is not constructed as 'anywhere' but as a debatable 'prototype for the urban future'. Thus, the 'publicness' of public experiments can produce conflicting views on what is shown and true.

Against this backdrop, the idea of reducing technological uncertainty through demonstration projects in cities seems paradoxical. The sociologist Harry M. Collins (1988, p. 725) even describes the problem as a twofold paradox: The first paradox lies in the fact that *proximity* to the places of knowledge production 'usually has the effect of creating *uncertainty*' due to the untidiness of experimental work. Scientific facts look more convincing from a distance (cf. MacKenzie, 1990).[59] Closer involvement in scientific testing and showing makes the

[58] In their introduction to 'The City', Allen J. Scott and Edward W. Soja stress that the contributers to the volume were 'encouraged to express her or his distinctive approach to understanding Los Angeles, even if this results in conflicting views.' The 'interlocking mosaic of descriptions' and case studies of the city was meant to foster urban analyses that are 'open to a diversity of interpretive positions yet is committed to a collective project that is theoretical and practical at the same time.' (1996 p. viii). This postmodern twist which invites different perspectives and also political controversy brings us closer to the question of place in the process of testing and showing innovation in public. The concept of truth-spots is principally suited to being 'streched to fit a wide variety of circumstances where believability and persuasiveness hand in the balance' (Gieryn, 2006, p. 29) and hence, to also analysing the emplacement of non-scientific knowledge.

[59] MacKenzie (1990, pp. 370–372) makes a similar point when he 'draws a correlation between closeness to the point of knowledge production (innovation, experimentation, testing etc) and (un)certainty. The so-called 'certainty trough' describes a situation in which a group of observers, that is neither close nor distant from the places of evidence production, accepts knowledge as truths, while those who are really close or further away from it are sceptical. This results from the fact that uncertainty is 'more acute for those closely involved in the production of knowledge', as they experience the contingency and messiness of evidence production, and

pragmatic decisions, debatable aspects, even pitfalls, behind seemingly coherent models, concepts and theories more obvious. It raises awareness of the interpretational efforts, inscriptions and performance skills upon which evidence production is based.[60] The second, related paradox is that public experiments suggest that laypeople or 'the general public' can draw conclusions on matters 'upon which scientific experts themselves cannot agree' (Collins, 1988, p. 725). In order to produce certainty about new technologies, scientific debates need to be closed and, as in the gentlemen's residences in the 17th century, public experiments need to be well-prepared, rehearsed and staged as 'epidictic' public demonstrations. Since this is all but easy in open-access sites and in front of the broadcasting media, well-staged public experiments are, according to Collins, closer to entertainment than scientific evidence. 'Demonstrations shade into *displays of virtuosity*' (1988, pp. 728, my emphasis).

We can conclude that these science studies challenge the above-described link between the implementation of innovation and diffusion in a twofold way. First, they show that the question 'technology trial or demonstration?' does not just depend on the timing and the maturity of a new technology. Instead, technology demonstrations that are supposed to reduce uncertainty, may become technology trials and ultimately *reduce certainty*. In other words, there may be a lack of convincing evidence when innovation is staged in the *wrong place* in front of the *wrong observers*. This may be due to the fact that access to demonstration sites is open, audiences are heterogeneous, close observers are not well-chosen and public displays are not well-enough prepared.

Second, the contrast between scientific laboratories, where homogeneous communities of practice construct and inscribe their evidence, and the more open settings of farms and fields shows that evidence is *situated* and produced in different material *formats*.[61] These formats differ with regard to their mobility and legibility. In other words, laboratory evidence is purified and inscribed, and it easily circulates once it has passed the threshold of the lab. But it is made for homogeneous epistemic communities and is thus difficult to contest from the

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outsiders/competitors who critique knowledge on non-technical grounds. (cf. N. Brown & Michael, 2003, pp. 11-12).

[60] 'Close proximity to experimental work, particularly where there is an element of controversy, makes visible the skillful, inexplicable and therefore potentially fallible aspects of experimentation, it lends salience to the web of assumption that underlie what counts as an experimental outcome.' (Collins, 1988, p. 726).

[61] In addition to that, Francesco Guala points to different forms of experimental validity. 'To be sure, some science travels from lab to lab without ever being faced with unconstrained reality. But not all science works that way, and indeed scientific knowledge would be a poor thing if it were limited to that' (Guala, 2003, p. 1197).

outside.[62] In contrast, evidence from 'the field', as is produced in the course of LED projects and also presented in this study, is still closely linked to its place of origin, which makes it vulnerable to reinterpretation, and therefore 'overflowing' (cf. Muniesa & Callon, 2007). In other words, we cannot expect what we learn from a particular demonstration project to be transferable to any other situation. At the same time, we can expect the places themselves to play a role in evidence production in projects.

Having said that, there is still a conceptual gap to be closed. So far, I have referred to studies on *scientific* evidence production, which does not exactly correspond to my focus on mostly non-scientific LED projects. However, three observations justify the analytic translation:

First, I am not the first to link scientific experiments and technology trials. Pinch argues that although drawing general parallels between science and technology 'is a hazardous process', there are equivalences between technology testing and scientific experimentation. According to Pinch—and others (cf. Constant, 1983; MacKenzie, 1989; Vincenti, 1990)—technology testing 'in many respects matches what scientists do at the laboratory bench' (1993, p. 29). While researchers produce scientific facts about the natural world, engineers produce technological artefacts. As Pinch points out, both practices rely on an act of projection:

> '[W]hether from the present to the future, from the present to the past, from the particular to the general, from the small to the large, or from the large to the small (as in miniaturization)- depends crucially upon the establishment of a similarity relationship. It is assumed that the state of affairs pertaining to the test case is similar in crucial respects to the state of affairs pertaining to the actual operation of the technology' (Pinch, 1993, p. 29)

Yet, what is perceived as similar and different depends on conventions, belief systems and interests. Similarity and difference are constituted 'within a wider framework of culture and action' (Pinch, 1993, p. 31). They are 'at the very heart' of how truth and falsehood are constructed in science. 'Valid test results depend upon the acceptance of a similarity relationship, and such a relationship can only be constructed within a body of conventions or within a form of life' (Pinch, 1993, p. 30). This is also outlined by the sociologist Donald MacKenzie who draws on Harry M. Collins's research on experiments in physics to analyse U.S. nuclear missile experiments in the South Sea (1989). As MacKenzie shows, conventions and perceptions of adequate testing do not just matter in the design process but also affect

[62] If exposed to heterogeneous epistemic cultures and views, not only facts or artefacts might be contested but also the experimental procedures through which they are produced in the first place (cf. Constant, 1983).

social acceptance of new technologies. 'If the relevant decision-makers cannot be persuaded that by their standards […] a novel technology has been properly tested, then the likelihood of their adopting the technology, or using it, is diminished' (MacKenzie, 1989, p. 430).

Second, there are experimental aspects in every technology implementation process (cf. Muniesa & Callon, 2007) due to systemic and recursive effects. Any society that strives for technological progress and knowledge is therefore 'unavoidably an experimenting society' (*Experimentiergesellschaft)* (Herbold et al., 1991, p. 29). Wolfgang Krohn has shown that experimentalism did not spring from modern science and technology but is deeply embedded in the culture of European society, with roots in the intellectual cultures of Renaissance humanists and artists, craftsmen and artist-engineers (2007). The release of any innovation 'will always be a step beyond existing knowledge […] In the final analysis, innovation means the invasion of unknown territory' (van den Daele & Krohn, 1998, p. 866).[63] Or as the sociologist William F. Ogburn put it: 'Without experimenting men lose their habit to look for novelty' (1969, p. 84). Real-life or self-experimentation can thus be considered a characteristic feature of our reflexive 'innovation society' (Hutter et al., 2013).[64]

Third, the above-described research gap justifies my analytical translation. Although reflexive learning and evidence production does not just occur in the sciences (cf. Kamp et al., 2004; B.-Å. Lundvall, 1988; Rüb & Straßheim, 2012), technology trials and demonstrations are micro-analytically underspecified (cf. Harborne & Hendry, 2009). Similarly, 'scientific experiments have been studied in microscopic detail' while technology presentations and their effects 'have received far less attention' (W. Smith, p. 450). This is problematic since technological experimentations can facilitate various 'investments in form' and engage their heterogeneous actors in various ways (Thévenot, 1986, 2007), including aesthetic or narrative formats (cf. Hutter et al., 2010). As Raghu Garud points out, evidence from events can also take on the form of narratives. While 'logico-scientific discourse attempts to convince by appealing to procedures for establishing formal and empirical proof, […] narratives attempt to convince by endowing experience with meaning through "verisimilitude"' (Garud, 2008, p. 1096). On the other hand, the focus on epistemic question should not make us forget that

[63] Wolfgang Krohn also shows that experimentalism did not spring from modern science and technology but is deeply embedded in the culture of European society, with roots in the intellectual cultures of Renaissance humanists and artists, craftsmen and artist-engineers (Krohn, 2007).
[64] Krohn and Gross link real-life experiments to the emergence of the 'knowledge society', in which 'conventions and norms are increasingly replaced by decisions based on expert knowledge and situation-specific experience' and 'uncertainty is becoming one of the key indications for a knowledge society' (cf. Beck, 1992; Gross & Krohn, 2005, p. 77; Krohn & Weyer, 1994).

public experimentalism also has a pre-reflexive, political dimension in the sense that it shapes realities (Böschen, 2013a; Latour, 2009; Marres, 2012). Public experiments may also overflow and unleash community-building effects whose influence on innovation goes beyond evidence production. Wally Smith gives an example that matches my notion of 'joint attention': Drawing on Ervin Goffman's concept of framed situations (1959), he suggests that technology displays not only produce evidence about new technical artefacts or innovative techniques but have also community-building effects. Besides letting spectators see for themselves, the demonstration might be seen as doing something else: letting spectators see what is seen', that is, what is seen by 'communities of knowers' (W. Smith, 2009, p. 475).[65] One might also say they create a public.

2.3 Towards a conceptual framework

In the previous section I outlined three ways of conceptualising LED projects, namely as technology trials and demonstrations (2.2.1), configurations of socio-material networks (2.2.2) and public experiments (2.2.3). I also already suggested that some perspectives suit my project better than others. In particular, the notion of diffusion inherent in most of the policy reports and innovation-management literature on state-funded innovation projects raises important analytical issues but does not match my interest in site-specific adaptations and reinventions of LED lighting. In contrast, social-scientific studies show that innovation goes on during the implementation of new technologies (Akrich, 1998; Oudshoorn & Pinch, 2003; Rammert, 1990). They also critically explore the effects of real-life experimentation on society (Groß et al., 2005; Krohn & Weyer, 1994) and experimental governance in the context of urban technological transitions (Evans & Karvonen, 2014; Karvonen et al., 2014). This research also refines, or challenges, the findings of policy-oriented and management research on innovation and technology implementation as outlined in Table 2-2.

[65] Further examples can be found in the literature on field-configuring events offers ample examples (Lampel & Meyer, 2008; Moeran & Pedersen, 2011).

Lessons learnt from research on early public installations of technological innovation		
Analytical issue	Macro-analytic perspectives	Micro-analytic perspectives
Testing or showing?	Depends on technological maturity and project timing	Depends on spatial settings and the heterogeneity of audiences
Smooth collaboration or politicisation?	Depends on risk-sharing and competent producers and users	Depends on 'interessement' in socio-material networks and enactment of configurations
Evidence production and dissemination of information	Requires active management of information, top-down or peer-to-peer information channels	Requires deliberate placing and project design, involves situated evidence production and observers

Table 2-2: Contrasting perspectives: Policy-oriented versus social-scientific innovation research.

As we can see, the different strands of literature highlight a number of different aspects that will be explored empirically in this work. Most importantly, they refer to different modes of implementing new technologies. Implementation formats range from state-funded demonstration projects to scientifically designed urban laboratories. Yet my research interest is also more general. In order to explore how LED lighting is introduced in public lighting I studied and compared six very different but generally rather low-key implementation projects. To study and analyse their variety and dynamics I made two conceptual decisions: First, I conceptualised LED projects in as neutral a way as possible, as 'early public installations'. Second, I developed a matrix (Figure 2-1) that links 'testing and showing' to the heterogeneity of observers, as will be outlined in the remaining two sections of this chapter.

2.3.1 Early public installations

The decision to frame LED pilot projects and showcases as 'early public installations' was a conceptual choice. It allows me to analyse LED projects as events in which innovation, technology and the city come together. While the adjective 'early' refers to a moment in the innovation process, 'installation' refers to a moment in the social life of the technology. The fact that these two moments come together 'in public' makes the projects an interesting case for exploring innovation as an open social and political process of invention and valorisation.

‘Early’

In line with my non-linear understanding of innovation processes, ‘early’ does not refer to a stage of diffusion but should be understood as a relational category. Early encounters with innovation breathe a spirit of newness as they create surprise or irritation and produce relations that have not yet been tested and are marked by uncertainty (Callon et al., 2009; Hutter, 2010). They prompt actors to ‘engage in exploration’ before they have tested, made sense of and attributed value to the novelty (Thévenot, 2011).[66] Early encounters happen constantly in innovation processes. In chapter 4 we will see that LED technology surprised and is still surprising its researchers and developers in their laboratories. Its fast development also took the traditional European lighting industry by surprise and was discovered by innovation policy makers in the late 1990s. In the context of public lighting, the years 2011 and 2012 were still a period in which urban actors, including the municipalities of Lyon and Berlin, had their first hands-on LED experiences.

Early encounters can be risky and costly, especially when they take place in non-standardised public settings (Potts, 2011).[67] They challenge taken-for-granted framings, can unravel coordinated interactions and create situations that are too complex to grasp.[68] In the case of *early* LED projects, the new technology is installed before it has been tested, certified and ‘black-boxed’ (see 2.1).

This conception of early installations differs from the notion of early adoption, as it refers to the relation between the new and the familiar world and not to the relationship between first adopters and laggards (cf. E. M. Rogers, 1995). Early encounters are unreproducible. Later encounters differ from early ones, as they can build on already tested and established relationships. In other words, while the time horizon of early adoption events relates to the

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[66] Laurent Thévenot describes exploration as a ‘relation of a person to his or her environment which is situated below the public recognition of an innovation. It resides under the level of games or play activities which are equipped with rules and is not yet aggrandised into the public worth of inspiration […This] ‘explorative engagement stands in a relation of high tension to the familiarity engagement since it is oriented towards a good which assumes the maintenance of an unfamiliar relation to the world’ (Thévenot, 2011, p. 51).

[67] Jason Potts has stressed the facts that such early encounters happen all the time because novelty is ‘abundant’ in a changing world. Yet, such encounters often pass without consequences because they are potentially costly for those who meet the new and are supposed to assess it. Potts suggests that curated events can ‘bundle novelty’ and enhance the positive evaluation of newness (Potts, 2011, pp. 162-183).

[68] Latour distinguishes between ‘complex’ simultaneous and co-present interaction on the one hand and ‘complicated’ interaction involving frames and ‘the successive presence of discrete variables, which can be treated one by one, and folded into one another in the form of a black box’ (Latour, 1996b, pp. 233, see 231).

global innovation process, the time horizon of early installations is the local situation of adoption.

'Installations'

The term 'installation' seems familiar, unpretentious and unproblematic. Yet it nevertheless deserves some clarification. In practical terms, public lighting by definition requires an act of installation, as only *fixed* equipment qualifies as public lighting (Van Tichelen et al., 2007-01). Theoretically speaking, putting technology into place is ontologically interesting: While 'early' refers to transformative moments in the innovation process, 'installation' marks a transformative moment in the social life of a technical artefact. It is the moment in which an LED luminaire becomes part of a larger technical system or 'constellation' (Rammert)[69]: It is materially linked to larger technological infrastructures such as electricity grids and light control systems and becomes subject to maintenance work and repair interventions, and hence a part of the socio-material network of public lighting.

Technology installations are also the moment in which humans delegate an activity to a technology and thus black-box it. Bruno Latour explains this using the example of a door opener. According to him, the *installation* of door hinges establishes a new time regime: 'Once the hinges are in place, nothing more has to be done apart from maintenance (oiling them from time to time).' In contrast, hiring a human door opener or groom fails 'to modify the time schedule':

> 'Although they appear to be two similar delegations, the first one is concentrated at the time of installation, whereas the other is continuous, more exactly, the first one creates clear-cut distinctions between production, installation, and maintenance, whereas in the other the distinction between training and keeping in operation is either fuzzy or nil. The first one evokes the past perfect ("once hinges had been installed…"), the second the present tense ("when the groom is at his post…"). There is a built-in inertia in the first that is largely lacking in the second… (Latour, 1992, p. 231).

[69] Rammert argues that the notion of 'systems' wrongly suggests that socio-technical interactions are reliable and stable so that we can trust in them. In order to 'avoid wrong fixations' and highlight the openness and malleability of such 'systems' he proposes the notion of the 'constellation' which suggests that humans, machines, programs interact in temporally and spatially distinct mixed arrangements, which are quite stable but are open to recombinations and change (Rammert, p. 9).

Analogously, the installation of LED lighting means a technology-specific and, as we will see, also a project specific delegation, which distinguishes dimmable, digitally controllable LED technology from 19th century gas technology which was lit by lamp lighters and 20th century electric lighting which is lit via ripple control. It also establishes innovation-specific time regimes: The installation of new lighting technology also marks the beginning of maintenance intervals and calculations of its operational lifetime. The question of *when to install* an expensive innovation such as LED technology very much depends on this time regime, as it directly relates to the total cost of ownership, and hence determines the amortisation period of an investment.

'In public'

Installing LED technology early *in public* refers to the socio-spatial *and* political dimension of urban innovating. In practical terms, the installation activities are 'public' because they are performed in urban public spaces, with tax money and by public service actors. However this again has conceptual implications. As mentioned above, it makes a difference whether newness is presented to a homogeneous public of expert observers or heterogeneous *publics* with different personal, professional or cultural backgrounds. In order to be recognised, experienced and evaluated or contested 'the new' must be shown to observers. Yet its valorisation becomes tricky if their familiar modes of engaging with their worlds (Thévenot, 2007), their 'professional vision' (Goodwin, 1994) and epistemic cultures (Knorr-Cetina, 1999)—in short, their evaluative principles—are not the same.

Against this backdrop and based on what we have learnt above, 'in public' can thus be understood as a particular socio-spatial condition that grants heterogeneous observers open access to the places where LED installations take place, and therefore differs from other sites of innovation such as R&D laboratories or market places. On the other hand, it is *only* a condition. As we will see, the plurality of heterogeneous views is not always enacted, which brings us to the second, political dimension of publicness.

The physical *observability* of early LED installations turns them into specifically urban 'sites of the social' (Schatzki, 2010). As Robert Schmidt and Jörg Volbers outline, urban public spaces in particular produce a 'joint attention' that structures social interaction through subtle practices of identification and distinction (2011a, p. 38; 2011b).[70] Such practices of mutual observation or social control are culturally contingent (Sennett, 1969, 1990). They can have stabilising effects or lead to controversy. To ‘make things public’ is the opposite of ‘black boxing’ them (Latour & Weibel, 2005). It can imply that existing relationships are called into question, that taken-for-granted knowledge is contested or silent spectators become protestors or take on the role of spokespeople.

Based on social-scientific research and historic accounts of urban lighting (9.) we can principally differentiate three situations in which public lighting infrastructures become public: The first relates to sensory aspects: Black boxes are opened when technological configurations do not work as they should (cf. Rip & Kemp, 1998, p. 30; Wynne, 1988). ‘Invisible’ urban lighting infrastructures become visible in the case of technological failure (cf. David E. Nye, 2010). Similarly, public lights become visible if they make a difference in familiar urban spaces—look different or illuminate a street more brightly or in a different light colour. Such ‘visibilisations’ increase the likelihood that public lights will be positively or negatively evaluated, which leads us to the second situation. The second situation involves the problematisation of social or socio-material relationships: public lights can turn ‘from matters of fact’ into ‘matters of concern’ (Dewey, 1954; Latour, 2004, 2005). Such controversies can relate to urban design or ecological issues and are as old as city lights (Hasenöhrl, 2015) and lead to the formation of ‘issue networks’ (Marres, 2007). Third, public lights may be a part of urban political agendas. As such, they might be positively connoted, for instance as a solution to a problem like climate change or as a symbol of progress and innovation (Binder, 1999).

In public thus refers to a specific socio-spatial condition that becomes consequential for innovation if the plurality of perspectives and personal engagements turns political—if black boxes are opened, evidence becomes controversial or public justifications are celebrated or rejected. It thus seems that testing and showing LED technology in the public spaces of cities stands in the greatest possible contrast to laboratory trials and technological demonstrations in showrooms. In the last section of this chapter, I will present my categorisation of public testing and showing.

[70] They further argue that observation can foster poesis—in other words creative imitation—by enhancing the distribution of embodied and tacit knowledge (R. Schmidt & Volbers, 2011a, p. 30). A similar argument has been made in innovation studies on spatial proximity and openness (Penn, Desyllas, & Vaughan, 1999; Rantisi, 2002) and in diffusion research, where ‘observability’ is considered an important factor (see 2.2.1, Magill & Rogers, 1981).

2.3.2 Testing/trying and showing in socio-material networks

As we have seen, the difference between risky technology trials and reassuring demonstrations is not clear-cut (cf. Harborne & Hendry, 2009; Hendry et al., 2010). The success of demonstrations of innovation does not only depend on the right timing and the maturity of technologies, but also on *where and in front of whom* it is staged. These insights from social-scientific research on public experiments and scientific knowledge match perfectly well with my definition of innovation as something that needs to be recognised as new and better by *observers* (Braun-Thürmann, 2005) and are even useful to further specify it. We have learned that it matters whether places are open for everyone or if only select groups of observers have access. '*Showing* innovation' to heterogeneous audiences is risky as it might produce diverging interpretations of what was shown. If observers are sceptical, ignorant or uninformed, it is more difficult for experts to control the perception of public technology demonstrations (Collins, 1988).

The following matrix (Figure 2-1) builds on my literature review and maps out eight situations of testing and showing in front of more or less heterogeneous audiences. The most homogeneous audience I have in mind are groups of actors with the same professional background—e.g. lighting engineers. The eight categories I propose to describe these situations are inspired by the above-quoted literature on 'public experiments'. Since this research mostly focuses on *scientific* knowledge production, I have reserved the notion of 'experiments' and 'laboratories' for situations in which scientists play a role and use different categories, like 'test site' and 'technology demonstration', for non-scientific testing and showing. Furthermore, my categorisation is a *matter of definition* since I combine concepts from different strands of literature that do not necessarily relate to each other and might overlap conceptually. Therefore, I briefly outline how I defined and applied these eight categories in my case studies in chapter 6. I start with the most intimate situation (lower left corner, Figure 2-1).

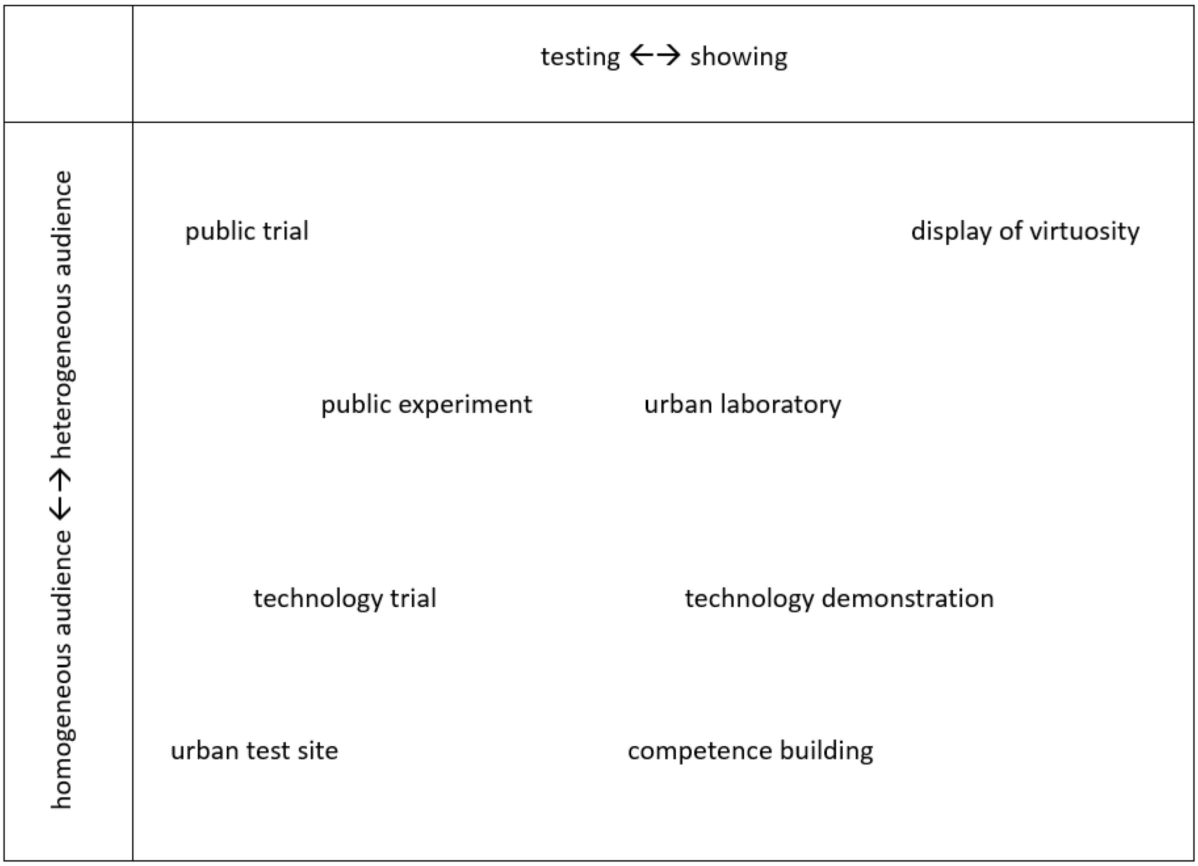

Figure 2-1: Conceptual framework for analysing public testing and showing.

Urban test sites are situations in which technology users and/or innovators try a new technology or technological solution, *without* the intention of raising public attention. The scientific analogy is 'the field'. Examples are LED test streets.

Competence building happens if homogeneous groups of actors show their installation work *to each other*. It is a reflexive practice that can take place in the form of intra-organisational learning or peer-to-peer exchange on site.

Technology trials could be anything. I define them as situations in which actor groups with diverse (professional) backgrounds test *whether a new technology is compatible* with existing technological structures, with work routines and existing strategies. Such situations are typical for early public LED installations since such projects usually involve not only product managers, installers and municipal civil engineers but also urban planners or administrative staff.

Technology demonstrations are the equivalent to technology trials on the 'showing' side, that is, situations in which collaborating professionals from different backgrounds show new technologies, solutions or practices to each other with the *aim to reduce uncertainty* and coordinate their activities, for instance in the planning process.

Public experiments are more heterogeneous than technology trials in the sense that they involve scientists. As such they include reflexive *scientific evidence production,* which does not rule out 'practical' forms of inquiry, trial and error.

Urban laboratories are *publicised public experiments.* They involve scientific evidence production and elements of city marketing. As outlined above, it is sometimes difficult to say whether an 'urban lab' is only a label or metaphor or whether it relates to actual scientific and pragmatic inquiry.

Public trials are situations in which individuals or groups of technology users and innovators are challenged by lay audiences and/or in the media. In such situations, relationships are called into question, black boxes are opened and issues are raised.

Displays of virtuosity take place when experts perform well-rehearsed experiments and stage innovation in public without being challenged and without black-boxes being opened by their heterogeneous audiences.

In the matrix, I do not distinguish between *practical* and *reflexive* practices. However, it is obvious that Collin's 'displays of virtuosity' put a greater emphasis on non-reflexive modes of observation and valorisation than 'urban laboratories'. In the case of new lighting technology, non-reflexive observation can also occur in the positive form of awe and wonder (Hasse, 2007a; David E. Nye, 2015) or a sense of cosiness or conviviality (Bille & Sørensen, 2007; T. Edensor, 2015) or in the negative form as a perception of 'light nuisance' or glare (Hirdina & Augsburger, 2000). Furthermore, non-scientific observations and valorisation can also occur in the form of *reflexive* engagements, for instance when issues are addressed, arguments exchanged and justifications offered in public (Boltanski & Thévenot, 1991; Marres, 2007).

Similarly, testing can be understood in a practical and reflexive way. In the pragmatic philosophical tradition (Dewey, 1958), practical inquiry or experimental practices are not reserved for innovation but can be observed in various societal contexts. Callon (1986b) argues that the emerging network needs to be tested and tried to ensure that newly interested actors and artefacts are also mobilised. Nortje Marres (2009) calls it ‘testing the powers of engagement’. Both authors thereby refer to the *enactment of relationships* between both people or people and things. Similarly, Luc Boltanski and Laurent Thévenot argue that public justifications need to be tested. The attribution of value can thus be understood as an act of linking an abstract notion of ‘worth’ to a concrete thing or issue, for instance an innovation. An audience is indispensable because such ‘moral’ valorisations are only valid if they are shared in society. Against this backdrop, the authors describe this evocation of moral ‘worlds of worth’ in front of audiences as an *épreuve*, a test. In contrast, reflexive testing is performed in line with explicit, standardised methods or procedures and produces some sort of results that can then be shown to colleagues or published. Obviously, there are also different *degrees* of reflexivity. It would also be wrong to assume that moral and material practical trials are generally pre-reflexive. Of course, there are also unwritten laws and explicit rules, customs, etiquettes, and institutionalised procedures to be followed when testing interpersonal, material or moral relationships.[71]

I conclude, that the question of *how LED lighting is tested and shown to be observed and evaluated* in the real-world can only be answered empirically by looking at *concrete early public LED installations*. My matrix of testing and showing offers me a conceptual framework to analyse and interpret my data accordingly. How I collected this empirical data and in which concreate research situations will be described in the following chapter.

[71] In addition to that, there are sociologists who have reflected upon and made explicit the implicit cultural or cultural modes according to which we test relationships and value. The list of work that is relevant in my context starts with Georg Simmel who has written about our visual evaluations of the world (Simmel, 1908) and ends with recent work on valuation, valorisation (Berthoin Antal et al., 2015).

3. Methodology and approach

In this chapter, I will explain my research strategy and approach. I will start with a brief methodological introduction (3.1). and then describe the research process and case selection in more detail (3.2). Subsequently, I will explain how I collected and analysed my data (3.3) and conclude with a critical reflection on my approach and research activities (3.4).

My research interest lies not in theory building but in providing an exploratory analysis of early public LED installation projects. As I will show, a combination of multi-sited ethnographic data collection and grounded 'situational analysis' (A. Clarke, 2005) was perfect for studying 'innovation in the making' (Akrich et al., 2002a). This research strategy also allowed me to make sense of *ongoing* developments and *simultaneous* activities without denying the messiness of the situations. The aim of my contrastive comparison of six LED projects in two different cities was to explore the variety of public innovation.

3.1 Methodological considerations

The ANT perspective on innovation processes suited my project in three ways. First, Madeleine Akrich, Michel Callon and Bruno Latour call for sociological studies that 'restore innovation in the making without intervening in the explanation of those elements which are unknown until the end of the process' (2002a, p. 191). In my cases, I could not have known more even if I had wanted to. Some of the projects I analysed evolved while I was doing my research. Second, the three sociologists suggest that socio-technical analyses should take place 'where innovation is situated, in this hard-to-grasp middle-ground where technology and the social environment which adopts it simultaneously shape each other' (2002a, p. 205). Early public LED installations are such places. Third, the explicit focus of ANT studies on materiality was also very instructive. Light might be an immaterial phenomenon, but lighting cities and studying light technological innovation does not make sense without accounting for the materiality of artefacts, urban infrastructures and the built environment of cities.

But the ANT approach also has its limits (cf. Hård, 1993; Rammert, 1997b). Its principle of 'generalised symmetry' (Callon, 1986b) makes it difficult to account for the taken-for-granted cultural and historical meaning of city lights and institutionalised professional views and evaluative principles, as they have evolved in the past 300 years of public lighting in Europe (see chapter 9). Furthermore, the focus on spokespeople highlights their ‘powers of translation’ but does not explain why other actors and things are not heard or remain invisible. It also privileges the actual over the virtual (Farías, 2014), in other words, observable interaction over meaning-making. But most importantly, the ANT approach seems perfect for describing how the emergence of *one* network of actors and things forms around an innovation. Yet the context of this network is not taken into account, which makes it difficult for me to focus on the *interfaces* between two networks. After all, my aim was to *describe and compare* how an *existing* urban network and an *emerging* global network merge, and to then *explain* the differences.

Therefore, I deviated from the ‘pure doctrine’ and modified my research strategy in two respects. First, I focused on both *situations and processes*. Second, I followed not only the actors but also the ‘joint attention’ of light-related publics (cf. Moore & Dunham, 2014). As Robert Schmidt and Jörg Volbers argue, the attention that is paid to and mediated by artefacts and symbols creates a *relational public* space that surpasses the urban public space of cities (R. Schmidt & Volbers, 2011b). If I had limited myself to following the innovators, I would only have seen what they saw. Instead, I also talked to residents on the streets and ‘followed’ the documents and discourses in conferences and paid attention to my own changing experiences of public lights and night-time atmospheres (3.3).

The aim of my exploratory multi-sited ethnographic research was a ‘thick analysis’ (A. E. Clarke, 2003, p. 2; see also Fosket, 2002)— in contrast to an ethnographic ‘thick description’ (Geertz, 1973) or grounded *theory* (Glaser et al., 1968). Adele Clarke’s ‘situational analysis’, which is based on grounded theory *methodology*[72], offered a methodical toolkit that made it possible to achieve that goal (A. Clarke, 2005). In the following section, I briefly outline which problems ethnographic research and situational analysis solved for me.

3.1.1 Multi-sited and focused ethnography

Ethnographic data collection is a research strategy applied by ethnologists, anthropologists and sociologists that allows the researcher to develop an understanding of the everyday

[72] Katja Mruck and Günter Mey distinguish between grounded theory methodology and grounded theory. While GTM refers to the entire approach, including its meta-theoretical assumptions and methodical elements and procedures, grounded *theory* refers to the analytical outcome and results of a given empirical study (2009, p. 104). The genre of ‘middle-range theories’ as an adequate theoretical form for thinking about human society was proposed by Robert Merton (1968).

worlds of the actors s/he studies (Honer, 1993). It is particularly suitable for revealing taken-for-granted views and routine practices. In that sense, my ethnographic approach allowed me to explore the 'invisible' expertise that it takes to light cities and the different perceptions and professional visions of lighting engineers, lighting designers and laypeople (Goodwin, 1994).

This field work included having conversations with experts, collecting documents and image material and, of course, conducting participant observations during conferences and trade fairs. LED installations and expert activities on the streets of Lyon and Berlin were observed in a focused way. Hubert Knoblauch (2001) describes such 'focused ethnographies' as a special form of ethnographic praxis used in the context of technical systems development (J. Hughes, King, Rodden, & Andersen, 1994). It is characterised by its focus on a specific aspect of a phenomenon, like the site-specific installation and use of LED technology. In contrast to 'conventional' ethnographic praxis, the focused method is compressed or 'intensive': data is collected and analysed in a short amount of time (2001, p. 129). Accordingly, I only spent x hours in total on the LED installation sites observing and talking to residents. However, on a more general level, my ethnographic research was quite 'conventional'. I became interested in 'innovation in lighting' late in 2008 and became immersed in the research field for almost six years.

Ethnographic research helped me solve a central analytical problem: When describing my project, I refer to the implementation of LED lighting as a 'local' phenomenon and its production as a 'global' innovation process. Yet this distinction is problematic. From the perspective of a participant observer, international conferences or trade fairs are just as local as installation sites. Only the international backgrounds of participants and dispersed production of LED products justifies the label 'global'. Similarly, most 'local' actors I met travelled and worked in different places. LED products link the 'local' act of installation to the global industrial value chains. Last but not least, the urban installation sites are not purely 'local', as outlined above (Berking, 2001; Massey, 1993; Sassen, 2011). City images are co-produced by visitors, and these images travel around the world, as is most evident in the case of Lyon 'City of Light'. Thus, the labels 'global' and 'local' do not relate to geographical places but to the circulation or stickiness of actors and things in these places.[73] In order to capture the 'local' or 'global' realities of LED projects, I had 'to examine the circulation of cultural meanings, objects, and identities in diffuse time-space' (cf. Appadurai, 1988; Marcus,

[73] This links my project to notions of 'glocalisation' (Swyngedouw, 2004) and the idea of 'relocating innovation' (Suchman, 2011; Suchman et al., 2008).

1995a, p. 96). George E. Marcus's 'postmodern' multi-sited ethnography offers instructions how to do this by 'following connections, associations, and putative relationships.' (see also Holmes & Marcus, 2005; Marcus, 1995a, p. 97).

Like the ANT approach and situational analysis, multi-sited ethnographic research rejects the idea of local and global levels of analysis (Figure 3-1). Instead, 'the global' is observed in 'the local'.74 Marcus proposes a set of research techniques, which he describes as different modes of following (1995a, p. 106). One can follow the people, the things, the metaphors, the stories or allegories, biographies or conflicts. Compared to the ANT approach and its limited focus on spokespeople, these modes offered a much broader perspective that also allowed me to 'follow the attention' and learn more about the 'silent observers' of public lighting, i.e. the residents.[75] The implications of this research strategy were most relevant in the case of the Berlin gaslights, as outlined in more detail below.

3.1.2 Inspired by situational analysis

While my data collection method was ethnographic, my data analysis was inspired by situational analysis (A. Clarke, 2005) and grounded theory methodology (Strauss & Corbin, 1994). Grounded theory methodology is also known as 'a method of discovery' (Charmaz, 2006). As such it seemed ideal for exploring the empirical and theoretical intersections of innovation, cities and technologies in an emerging research field. Light and cities have only been more systematically studied in social scientific research in the past few years. In this situation, the conceptually open and flexible tools and principles of the grounded theory toolkit proved very useful. Yet my research goal was not the development of a grounded *theory*. Instead, I applied grounded theory *methodology* to open up the data and develop a 'thick' situational analysis.[76] The fact that data collection and analysis occurred

[74] George E. Marcus considers this collapsed methodological distinction between global and local, between 'world system' and 'lifeworlds' as a reflection of the shifts in the political and economic system. The 'post-industrial' flexibilisation, specialisation and globalisation of economic regimes and political interdependence also require new social research methods (Marcus, 1995a, p. 97).

[75] In the case of public lighting, the notion of 'attention' has a particular methodological relevance. As Bernhard Waldenfels argues in his 'phenomenology of attention' (2004) paying attention produces gravity fields in which things matter more or less. In the case of LED lighting, this sensory perception of the innovation is not only crucial but also problematic. While the experts' senses are trained to perceive even slight variations in light, those who are affected by it on a daily basis might not perceive the difference and/or not pay any attention. The phenomenon of 'paying attention' is also key to the diffusion of innovations as it facilitates imitation (cf. Barry & Thrift, 2007; E. M. Rogers, 1995; Tarde, 2003).

[76] Mey and Mruck justify this partial deployment of grounded theory methodology (GTM) as a toolkit. They argue that it can be useful to apply GTM elements if the goal is to build abstract categories from empirical data.

simultaneously thereby allowed me to continue to integrate new information until the very end of the writing process.

Situational analysis is a relational continuation and modification of grounded theory, especially Anselm Strauss's version of it.[77] It shifts the focus from processes to *situations* and from context to *relationships* between actors and also artefacts. Clarke's explicit and 'post-essentialist' aim is to acknowledge and preserve the messiness of the realities she explores.

Situation are understood as the 'ultimate unit of analysis' (A. E. Clarke, 2003, p. xxii) and as *research artefacts*: 'The situation of inquiry is empirically constructed through the making of […] maps' (2005: p. xxxv). Clarke's notion of 'situation' is based on different pragmatist 'scholarly contributions' and covers different aspects of social interaction and communication: its performative potential, the situatedness of knowledg*es* (in the plural) and also the idea that events can outlive their time and place (ibid: pp. 21-23).[78] Clarke's understanding should not be confused with Erving Goffman's notion of situations (Goffman, 1971). Hers is not restricted to situations of face-to-face interactions but is 'much broader and includes pertinent institutional and other meso/macro social formations' (2005, p. 35).[79] Thus, the situations of early public LED installations may potentially encompass the public lighting networks in Lyon or Berlin as well as the world-wide LED innovation systems. Whether and in what form the global is enacted in the local is an empirical question. In other words, Clarke's 'mapping exercises' (see 3.3.3) provide the analytical tools for revealing *what matters* in a situation. Figure 3-1 illustrates my focus on six situations in two cities.

But they also urge researchers to explain what they did and to 'not claim that GTM was applied' (2009, p. 148). Kathy Charmaz (2006), another *constructivist* developer of GTM, argues that the methodology is 'a set of principles and practices' rather than 'prescriptions and packages' and that the founding-fathers of GTM, Barney Glaser and Anselm Strauss (1968), themselves 'invited their readers' to use their strategies in their own way.

[77] For a more detailed description of the methodological differences between Glaser's 'empiristical' project (Strübing, 2004, p. 8) and Strauss's and Juliet Corbin's version of more comparative and procedural approaches see, for instance, Glaser (1992) or Charmaz (2006, p. 8).

[78] The 'scholarly contributions' are first, the so-called Thomas Theorem. In a nutshell, is says that 'situations defined as real are real in their consequences' (Robert K Merton, 1995). The second reference is a 'classic and deeply pragmatist paper' by C.Wright Mills on linguistic behaviour (Mills, 1940), which reads like an earlier version of John Austin's speech act theory (1962). Third, she cites Donna Haraway who 'would like to insist on the embodied nature of all vision' and proposes 'a doctrine of embodied objectivity', that is the acknowledgement of *situated knowledges* (Haraway, 1991, p. 188). Finally, Clarke's fourth source of inspiration blurs the temporal and spatio-material boundaries of situations. Drawing on Blumer and Peter Hall, she suggests that a situation is 'always greater than the sum of its parts' due to its 'gestalt' (A. Clarke, 2005, p. 23). One might as well call it its 'figure' (Suchman, 2012).

[79] Nevertheless—and in the tradition of symbolic interactionism (cf. Blumer, 1986)—Clarke also acknowledges the relevance of a 'mutual monitoring' that is facilitated by the co-presence of actors, artefacts and meanings.

All global, urban and project-specific aspects that matter are enacted or referred to by actors and are hence observable in the planning process. All that does not matter is still there but lies outside the analytical focus (outside the red circles).

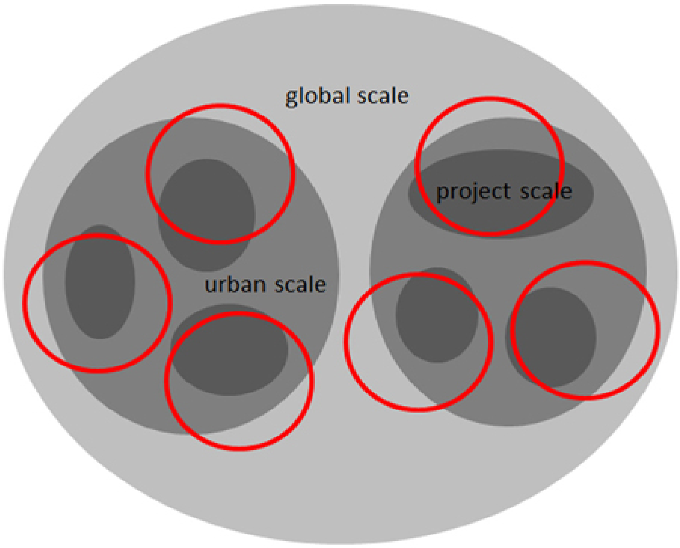

Figure 3-1: Global, urban and project scales in multi-sited situational analyses.

In line with ANT, Clarke rejects the idea of multiple levels of analysis or the idea of 'context':

> *The conditions of the situation are in the situation.* There is no such thing as "context". The conditional elements of the situation need to be specified in the analysis of the situation itself as *they are constitutive of it,* not merely surrounding it or framing it or contributing to it. *They are* it. (A. Clarke, 2005, pp. 71, her emphasis).

In contrast to ANT, Clarke also draws attention to shared ideas and collective imaginaries. The reality of the situation is materially *and* virtually enacted. Relations can be embodied and inbuilt or symbolic and imaginary, which makes the approach suitable for studying observable interactions and taken-for-granted professional assumptions or shared images.

Summing up, there are three reasons why situational analysis offers a quite unique and perfect approach for analysing the messy, boundary-blurring realities of early public LED installations. First, the iterative grounded procedures for simultaneous data collection and analysis allowed me to study an ongoing open-ended and multi-sited innovation process *in the making*. Second, it offers a set of *analytic exercises* that can be used to reveal not only gaps in the data but also the *missing links*: actors' blind spots and individuals, groups, things or issues that are overlooked or not represented. Third, situational analysis rejects the flat symmetry principle of ANT: Clarke's approach can account for people's ideas and worldviews and thus capture not only observable interactions, but also the differences between people's lifeworlds, personal and professional views and cultures (cf. Goodwin, 1994; Knorr-Cetina, 1999) and, most importantly, the quality of their relationships. As Tom Mathar suggests, Clarke is probably 'the first person to deliver a method of how one could engage in analysing the *quality of relationships*' (Mathar, 2008, pp. 10, my emphasis). For these three reasons, I happily accepted the challenge of 'making a mess' with my data.

3.2 The research process: Case selection, data collection and analysis

Situational analysis is based on and draws on the grounded theory methodology toolkit for both data gathering and analysis—despite their different analytic goals.[80] This means that analysis begins 'as soon as there is data.' (A. Clarke, 2005). Data collection and analysis take place simultaneously in an iterative process (Charmaz, 2006, pp. 5-6). This switching is a key principle of grounded theory methodology (Mey & Mruck, 2010, p. 616). A rigid procedural framework guides this research process. The key strategies are *constant comparison*, *theoretical sampling* and *memoing*.

In this section I will outline how I entered the field and selected my cases based on the principles of grounded theory methodology and situational analysis. To give the reader a concrete idea of both the research field and my work, I will immediately link my explanations to concrete problems and decisions that occurred in the research process. The basic technical terms are marked in italics and explained in footnotes.[81]

3.2.1 Research focus and field access

The research focus on LED technology in public lighting emerged in the course of earlier exploratory studies on urban lighting and innovation. Between 2009 and 2010, I conducted ethnographic research during light festivals and lighting trade fairs to explore 'showcases of

[80] As outlined above, grounded theory aims at theory building, while situational analyses produce 'thick analyses'. Clarke also explains that the 'root metaphor for grounded theorizing shifts from social process/action to social econolgy/situation—grounding the analysis deeply and explicitly in the broader situation of inquiry of the research project.' (2005: 37).

[81] I keep my explanation short since these tools have already been described in detail elsewhere (A. E. Clarke, 2003; Glaser et al., 1968; Mey & Mruck, 2009, p. to give but a few examples).

the new' (Schulte-Römer, 2013b). Soon, I found that LED technology was disrupting the lighting industry and offered new opportunities in urban lighting. I also realised that the technological innovation was not the only novel but deeply entangled with new political, scientific and socio-cultural developments. In 2010, I pursued this question of interrelated innovation and the co-evolution of social, political and technological newness in the field of urban lighting in an expert workshop held at the WZB (Schulte-Römer, 2010).[82] The expert discussion is reflected in my analysis of the 'global' developments in chapter 4. It was also important in terms of field access, as we will see below.

The decision to study early public LED installations was motivated by two considerations. From a pragmatic point of view, implementation projects are the link between R&D and technology use and offer a wonderful research opportunity in which the researcher can witness the introduction of technological innovation (cf. Rammert, 2000). They were perfect occasions for observing how LED manufacturers, their new products, technology users and citizens come together for the first time.

The next question was where to look for case studies. When I started my field work in 2011, I could have chosen from cases all over the world. Around this time, LED projects or displays in public lighting were mushrooming in Germany, Europe, the USA and Asia.[83] I decided to reduce the complexity on the global scale by focusing on Europe, but I allowed for variety and difference on the urban scale by studying projects in two different cities. Lyon seemed the most obvious choice. The City of Light is renowned worldwide for its competence in public lighting and for its light plans. Furthermore, I knew that Lyon was planning LED projects, and I had already met some of the local key actors. In particular, I was in touch with the Lyon-based city network LUCI (Lighting Urban Community International), which is very active in organising municipal expert exchanges and events, as we will see in more detail below.

The LUCI activities offered me a point of departure for my research and were important in terms of field access. In 2011, I became a LUCI member.[84] Furthermore, I received support

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[82] These non-technological developments will be further outlined below. They include light plans as a new instrument of urban governance (political), new medical treatments and approaches to light and health (science) and a socio-cultural reevaluation of the dark as is promoted in 'dark sky' initiatives and legislation against light pollution (cf. Schulte-Römer, 2010, forthcoming).

[83] In the USA, Los Angeles is a famous case of early and extensive LED adoption. In China, the government is pursuing an extensive demand pull-strategy and installed public LED lighting in very early stages of the innovation process (see chapter 4, Gu, 2009-07-22, #2366; Lin, 2011-07-01).

[84] The membership also allowed me to visit several conferences, to access reports and studies on the LUCI website and to have conversations with municipal lighting actors from all over the world, which helped me to

from the geographer Jean-Michel Deleuil, who is one of the first and few social scientists to work on urban lighting. He offered me desk in his laboratory in the civil engineering department at INSA Lyon (*Institut National des Sciences Appliquées*). But more importantly, his pioneering research, advice and profound knowledge of the Lyon lighting scene opened doors into the field and offered new perspectives. I spent three months in Lyon, from November 2011 until the end of February 2012,[85] studying municipal public lighting practices in general and LED projects in particular. The particularities of my research activities in Lyon and initial findings are described in more detail in my research report for the German Academic Exchange Service (DAAD, see appendix).

In Berlin, field access was easier since I had followed the urban lighting activities in my hometown since the beginning of my research. The local media frequently reported about public lighting issues due to the gaslight controversy and the restructuration of the public lighting service. When I returned from Lyon, I was already familiar with the local lighting scene. I also became a student member of the German lighting society, LiTG, and visited the 'light technological colloquium', which is regularly held at the Technical University Berlin and is a perfect place to meet and talk with Berlin lighting experts.

3.2.2 Contrasting cities

The choice of Berlin was motivated by the grounded research strategy of seeking maximal contrast.[86] My later findings confirmed that decision, which is also reflected in a comment by one of my interview partners: 'Lyon and Berlin, I would say, are really worlds apart. You have really chosen two extreme examples there' (Interview with a Berlin change agent in public lighting).[87]

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situate my findings. For the same reasons, I successfully applied for student membership of the Professional Lighting Design Association (PLDA) and in the *Deutsche Lichttechnische Gesellschaft* (LiTG).

[85] The research stay was financed through a DAAD scholarship.

[86] Maximal contrasts are used to explore the scope and variety of the phenomena in question. Minimal contrasts are used for refining, testing and elaborating grounded categories and concepts and for achieving saturation (Mey & Mruck, 2010, p. 616).

[87] OV: *„Es sind Welten, würde ich sagen, zwischen Lyon und Berlin. Da haben Sie sich wirklich zwei Extrembeispiele herausgesucht"* (sustainability consultant (EU), 2012-28-11).

However, Berlin had not been my first choice. Originally, I had planned to pursue my research in Frankfurt am Main.[88] Yet during my stay in Lyon I changed my research strategy based on memo-writing[89] and theoretical sampling[90] (see also Schulte-Römer 2012a, in German).

First, it became clear that '*the city'* as a whole did not constitute a useful *category*[91] for analysing and explaining the introduction of LED lighting. Instead, more concrete entities and the relationship between them mattered, for instance light plans, staircases and urban innovation policies. It seemed therefore less important to choose a city that equalled Lyon in size and importance[92] and more reasonable to focus on a city with similar characteristics on the urban scale. In this respect, the impact of the Lyon light festival and the Lyon trade fair LumiVille proved less straightforward than I had expected, making Frankfurt am Main, with its Luminale festival and Light+Building trade fair, less compelling for my comparison.[93]

Instead, my Lyon research drew my attention to the interactions between public lighting services and citizens. The municipal lighting experts in Lyon considered the Lyonnais indifferent to mundane street lighting. Accordingly, I categorised the local laypeople as *silent observers* who do not respond to innovation in lighting unless they feel disturbed. In this respect, the politicised issue of the Berlin gaslights and civic protest against their removal presented a maximal contrast and unique research opportunity.

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[88] I had assumed that the city's light festival and annual trade fair LumiVille (now CapUrba) would shape the urban configuration of light-technological innovation. Based on that assumption, Frankfurt am Main, with its biannual world leading trade fair and accompanying light festival, the Luminale, seemed a suitable contrasting case. It parallels Lyon in size, political and economic importance as commercial and finance centres.

[89] Memo-writing is a crucial research practice in GTM. In this process, the simultaneity of data collection and analysis finds its expression, as field observations and insights are reflected on, condensed and linked to concepts and categories. 'Memo-writing leads directly to *theoretical sampling*. Theoretical sampling is strategic, specific, and systematic,' writes Charmaz (2006, p. 103).

[90] Theoretical sampling is 'the grounded theory strategy of obtaining further selective data to refine and fill out your major categories.' (Charmaz, 2006, p. 12)In contrast to quantitative sampling, theoretical sampling does not aim to represent distributions of larger populations but 'directs you where to go.' (ibid: 100-101). It thus offers a controlled strategy for data collection and analysis. The researcher takes a piece of data as a point of departure in the subsequent systematic search for the next pieces of data.

[91] Charmaz writes about categories in the grounded theory process: 'Through studying data, comparing them, and writing memos, we define ideas that best fit and interpret the data as tentative analytic categories. When inevitable questions arise and gaps in our categories appear, we seek data that answer these questions and may fill the gaps.[…] As we proceed, our categories not only coalesce as we interpret the collected data but also the categories become more theoretical because we engage in successive levels of analysis. Our analytic categories and the relationships we draw between them provide a conceptual handle on the studied experience.' (Charmaz, 2006, p. 3)

[92] Lyon is the third city in France and is economically important. In Germany, Frankfurt am Main plays a similar role, while Berlin is a very different case. It is the capital, it is a *Land* (state), it is poor and much bigger than Lyon.

[93] The light festival aspect also does not contradict the choice of Berlin since it also has a festival of light. In fact, the privately organised event constitutes the greatest possible contrast to the municipally organised and traditional Fête des Lumières. Yet while the Lyon festival is relevant for innovation in public lighting, the Berlin festival seems not to be, as we will see below.

Furthermore, the municipal public lighting service and the Lyon light planning strategy proved important. Again, Berlin's privatised lighting service and the city's new light plan presented a maximal contrast.[94] Like in Lyon, the Berlin light plan encompasses the entire city but differs considerably in terms of planning practice, goals and LED lighting policies. The same is true for what I categorised as *urban public lighting networks*. While Lyon has a municipal lighting department, Berlin was the first city to outsource its lighting service in the form of a public private partnership. While the Lyon public lighting network is well-established and growing, the Berlin network dissolved after German reunification as will be outlined in chapter 5.[95]

Last but not least, my attention was drawn to transdisciplinary professional exchange and social-scientific research on lighting in Lyon. During my stay, I had the opportunity to attend the events and meetings of the regional Cluster Lumière and to witness how its outdoor lighting group established new contacts with international partners and other regional innovation clusters in the EU. They also set up a transdisciplinary 'public experiment', the DEDRA programme, in different communes around Lyon and Grenoble.[96] My host research laboratory carried out the social-scientific evaluation of the LED installations. Its head, Jean-Michel Deleuil, is also actively involved in a series of quasi experiments in Lyon (EVALUM), together with lighting engineers, the municipal lighting department and the local lighting industry (see 5.4.1). Again, Berlin has similar activities. In 2011, I attended a kick-off workshop of the regional cluster *Optischen Technologien Berlin Brandenbug* (OpTecBB, 2011-02-28). As far as I am aware, the initiative has not really kicked off yet.[97] In May 2010, the transdisciplinary cluster Loss of the Night started its three year research programme on the negative ecological, economic, cultural and social effects of light or 'light pollution'.[98] Both the French and the German light-related research projects were funded by national

[94] This assessment was also based on a qualitative telephone survey (Wagner & Schulte-Römer, unpublished document). The survey revealed that city-wide light plans had been drafted in several German cities and that their numbers were increasing (Schulte-Römer, 2011b). Yet Frankfurt am Main only had district-level light plans at the time.

[95] Frankfurt am Main would have represented a middle position as there is a close cooperation between the municipality and the local energy provider and light manager.

[96] In the course of DEDRA (*Démonstrateurs d'Eclairage public Durable en Région Rhône Alpes*), a number of private partners and research institutions, including INSA Lyon and the CSTB Grenoble, installed and evaluated LED street lighting demonstration projects. See: http://www.clusterlumiere.com/DEDRA-demonstrateurs-d.html, last access 2014-08-20.

[97] From Lyon, I contacted one of the initiators of the event, a researcher at the Department of Management at the *Freie Universität Berlin*, and learnt that they planned to continue the workshop series with a special focus on the lighting sector (FL2, 2012-01-17; see alsoSydow, Lerch, & Staber, 2010).

[98] http://www.irs-net.de/forschung/forschungsabteilung-2/Nachtverlust/index.php, 2013-08-10.

governmental institutions and were, to a greater or lesser extent, related to the lighting industry. LED lighting was a central focus of all research projects.

The social-scientific research on urban lighting in Berlin and Lyon was not only relevant for my comparison but was also methodologically consequential. In Lyon, I talked with the light researchers at the INSA laboratory.[99] In Berlin, I had regular contact with my colleagues from the Loss of the Night research cluster at the ISR Leibniz Institut in Erkner and the ISR at the TU Berlin. In particular, I worked together with the political scientist Katharina Krause (IRS) who also studied early LED installations in Berlin.[100]

Summing up, the contrast between Lyon and Berlin sharpened my research focus. It also limited my choice of eligible LED installations. There might have been earlier and more innovative cases in other cities,[101] but only a limited number of early public LED installations were carried out while I was doing my research in Lyon and Berlin. In this respect, the timing of my field research was perfect: Both cities only began to install LED lights in 2011.

3.2.3 Selecting and comparing early public LED installations

On the project scale, I approached my research question in two analytic steps. First I followed the actors to reconstruct the installation processes. Second, I followed the attention of the actors, observers and silent audiences of the projects. My focus on LEDs thereby narrowed my perspective on the projects in the sense that I did not trace all the projects' histories in detail. In cases like the Place Bellecour and Berlin gaslights replacement projects, which had already been planned and negotiated for decades, I limited my research to the period when LED lighting became an option and was planned and installed. Yet I soon realised that my three-month stay in Lyon would not be long enough to study all the different stages of the ongoing LED projects. Furthermore, there was not much to observe. In a memo, I described the problem as follows:

[99] The doctoral students I met focused on lighting practices in Vietnam and in the favelas of Rio de Janeiro, Brazil. I also discussed the methodological problems of light-related qualitative research with undergraduate students.
[100] Despite our different research interests, Katharina Krause, her student colleague Christoph Toschka and I also conducted interviews together (Leibnizstraße was the only project in which our foci overlapped). The Loss of the Night team also organised some interesting events (a kick-off Workshop 2011 and the conference Bright side of Night in 2013) and we attended conferences and field events together (VDE Berlin, AAG Los Angeles).
[101] For instance, Hannover is famous for its LED test streets in Germany. In France, Toulouse is conducting interesting and highly progressive experiments with LED lighting control systems.

‘Originally I had intended to just follow the municipal lighting engineers while they were doing their work. Yet there is little to see during daytime installations. The interesting decisions are made much earlier, for instance in the procurement process’ (2012-12-16, p. 4).

Therefore, I adopted a piecemeal strategy, widened my focus and collected data on LED-related activities on the urban scale. I attended conferences like the Forum LED in Lyon (2011-12-08a), the Berlin and Lyon light festivals, and trade fairs (2009-10-19, 2010-06-03, 2010-10-06, 2011-11-15, 2011-12-09b), and I visited manufacturers’ showrooms and test laboratories (2011-03-07, 2011-11-28, 2011-12-06 2012-01-12).

The project-related data collection was later refined in the course of my comparative analysis. From all the data I had gathered, I eventually chose three cases of early public LED installations in Lyon and three in Berlin, which allowed for maximal and minimal contrasting. There were some projects in Lyon which I could not consider for my analysis. In Berlin the choice of LED installations was more limited although I extended my data collection phase.[102] As Table 3-1 illustrates, the six cases exhibit great differences with regard to their *project scale* and *scope of innovation*.

Case study	Project scale	Scope of innovation
Lyon		
Place Bellecour	Long-term urban design and regeneration, involving light planning	Customised dimmable LED luminaires, site-specific collaborative design
Rue de l’Oiseau Blanc & Rue Thénard	Public lighting project, permanent replacement of outdated technology	New standard LED luminaires
Montée du Boulevard	Urban regeneration and LED pilot project involving light planning	New dimmable standard LED luminaire and innovative fixture, pilot installation
Berlin		
Leibnizstraße (Berlin)	Public lighting LED demonstration project and urban laboratory	New dimmable standard LED luminaire with lighting control system
Falckensteinstraße & Neukölln	Politicised LED pilot project, replacement of outdated technology	Customised LED lanterns, collaborative design
Altonaer Straße	Product presentation and sampling, for replacement of outdated technology, *temporary installation*	New standard LED with lighting control system, collaborative development

Table 3-1: Six projects at a glance.

The six projects range from *large-scale* regeneration projects whose actors and audiences are bigger and more heterogeneous, like the one on Place Bellecour, to *small-scale* LED replacements with only a few actors, as in the case of Rue de l’Oiseau Blanc and Rue Thénard. The project scale affects the heterogeneity of the actors involved in the projects and

[102] In Lyon, the projects that are not part of this analysis include some the smaller experimental installations in 2011, like a presence-control LED system on a pedestrian bridge and LED luminaires on a road bridge, as well as later large-scale LED projects like the refurbishment of a typical street lantern and the introduction of a presence-control lighting system in a residential quarter in 2013. In Berlin, the only projects I did not consider were some earlier singular examples of LED gaslight replacements. Instead, I had to include a temporary installation of LED luminaires in Altonaer Straße to add more variety to my case studies.

was consequential for my analysis. Furthermore, the scope of innovation affects the need for adaptation on the local level. Customised solutions are designed specifically for the site in question. Standard luminaires or lighting control systems are off-the-shelf products that are already adapted to mainstream lighting practices. In this respect, the results of the comparison between the customised LED solutions in Berlin and Lyon were particularly interesting with regard to the question of in what form LED technology was introduced.

In addition to that, I differentiated between projects that were, according to their planners, designed to test technology or to show innovation. As we will see in chapter 6, the above-described conceptual assumptions about public experiments confirmed: Technology demonstrations can turn into public trials and vice versa (see 2.2 , Collins, 1988).

3.3 Data collection, analysis and preparation

'All is data,' states a famous dictum of grounded theory methodology. This also applies to situational analysis. Yet there are different ways to collect these data: by observing processes, by studying written accounts and artefact and by asking questions and listening to answers (Deutscher, Pestello, & Pestello, 1993). In the course of my multi-sited ethnographic research I pursued all three strategies. Expert interviews helped me to understand how those who are involved in early public LED installations plan, see and assess LED technology. Document analyses were helpful for reconstructing public and expert discourses on light and LED technology. Participant observations were crucial for understanding work routines and professional ways of evaluating LED lighting on site.

3.3.1 Participant observation, expert interviews and content analyses

Participant observations and site visits with lighting experts were crucial in multiple ways. First, they allowed me to understand what lighting experts do, especially their taken-for-granted, black-boxed work routines. Following the actors from site to site, I was able to witness how lighting professionals plan and evaluate public lighting. Second, accompanying them also improved my own sense for and visual appreciation of lighting. Today I am almost embarrassed to say that, although I had lived in Berlin for nearly ten years, I could not tell the difference between a gas lantern and an electric light when I started my research (3.4.1). Third, participant observations during conferences and light-related meetings or events revealed significant differences between the Berlin and Lyon public lighting networks. Lyon's lighting experts have an international presence that is also reflected in their multi-sited engagements. I met the city's municipal engineers during local, regional national and international events, conferences and meetings, where they actively participated in expert debates. I never met Berlin's municipal engineers in international contexts.

Yet the mobility of the actors and the fast-developing LED technology also made it difficult, in fact almost impossible, to be at the right place at the right time.[103] *Semi-structured expert interviews* helped me to fill the gap, especially with regard to the project stages that I had missed or could not witness, like the administrative interactions between municipal departments. They also allowed me to deepen my understanding of different professional views and LED-related evaluative frames.

I systematically chose my interview partners with regard to the roles they performed in the public lighting networks of their cities, for instance 'light manager' or 'municipal light planner'. Before every interview I did preparatory research to avoid obvious questions (Burnham, Gilland, Grant, & Layton-Henry, 2004, p. 211). The list below offers an overview of who I talked to in Berlin and Lyon (Table 3.2).

The interviews were structured in three parts, with questions about the interviewee's work, her or his views on LED technology and how they had been affected by it, and questions about public lighting practices in Lyon or Berlin. The interview questions often emerged during participant observations and as a result of category building and constant comparison. Most interviews were conducted face-to-face. They lasted one to two hours, were recorded and later transcribed in French or German. Conversations, for instance those conducted with electricians and municipal personnel during LED installations, were shorter, more loosely structured around specific questions and written down later in protocols.

[103] In Lyon, I was not sure at the beginning if the public lighting experts had understood what I was looking for and therefore lived in constant fear of not being informed about their LED-related activities and missing important events like the installation of LEDs, measuring activities or meetings. Yet there was no need to worry. Most of the time they called me, often at very short notice, to invite me to their often very spontaneous LED expeditions.

Interviews Lyon	Interviews Berlin
DEP lighting engineer (2012-01-06)	SenStadtUm civil engineers (2012-12-05)
DEP head of maintenance (2012-01-18)	SenStadtUm engineer & lighting engineer (2012-12-11)
Lighting designer, Placee Bellecour (2012-01-09)	Head light manager (2013-06-10)
Lighting designer, Montée du Blvd. (2013-09-20)	TUB lighting engineer (2013-02-06)
Lighting installer (2012-01-27)	Lighting engineer and planner (2012-12-13)
Municipal light festival organiser (2012-01-06)	SenStadtUm urban designer (2010-02-22)
Cluster Lumière managers (2011-12-21)	Lighting designer, Altonaer Straße (2013-02-15)
Telemanagement systems expert (2012-01-26)	Product designer, Altonaer Straße (2013-08-22)
Interviews France	Interviews Germany
Municipal consultant (2012-02-03)	Sustainability consultant (EU & DE), (2012-28-11)
Sustainability consultant (2011-12-15/16)	Standardisation professional (EU & DE) (2010-12-02)
Product manager-Montée du Bvd. (2013-10-04)	Conversations Berlin
Ministerial consultant (2012-02-02)	SenStadtUm civil engineer (2013-05-22)
Lighting consultant (2012-01-11).	SenStadtUm civil engineer (2012-11-14)
Conversations Lyon	Ministerial policy maker (2010-07)
DEP head light planners (2011-12-02)	SenStadtUm lighting team and manager (2013-05-29)
Standarisation professional (2011-12-09)	Public lighting professional (2013-05-29)
Product managers-Place Bellecour (2012-04-15)	Lighting designer/lighting manufacturer (2010-09-21)
Municipal lighting engineer (2013-09-19)	Management Researcher, FU Berlin (2012-01-17)

Table 3-2: List of interviews and conversations, Lyon and Berlin.

Finally, *document analyses* added to my understanding of the urban and global LED-related innovation activities. The key sources were EU documents, newspaper articles and project reviews, including any imagery. The European Commission's activities were documented and reflected on in a comprehensive assessment of street lighting infrastructures in the EU member states (Van Tichelen et al., 2007-01) and a number of policy papers, reports and project evaluations (2011-12-15b; 2013-06; Valentová, Quicheron, & Bertoldi, 2012). Furthermore, I obtained concise information about ongoing innovation processes from market analyses (e.g. Baumgartner, Wunderlich, & Wee, 2011-07) and industry reports (e.g. The

Climate Group, 2012-06) or the LED Magazine newsletter. I see these documents as a hybrid form of data—an object of analysis and source of information.[104]

Newspaper content analyses were another means of following the ‘joint attention’. One comprehensive document analysis focused on the Berlin gaslight debate, which was reported and commented on in both local and national German newspaper, especially in the local and cultural sections.[105] A second analysis focused on the ‘public justifications’ (cf. Boltanski & Thévenot, 2006) of LED lighting in German and French newspapers. The articles were coded and analysed by WZB intern Sophian Sørensen (2012). The study confirmed that a ‘green’ image or justification for LED lighting (cf. Thévenot, Moody, & Lafay, 2000) prevails in the mass media. Both analyses were done with the qualitative coding and research software Atlas.ti.

3.3.2 Multi-sited data collection

The six case studies at the heart of my analysis involved LED installations between October 2010 (Place Bellecour) and May 2013 (Altonaer Straße). Since not all LED projects were installed and planned during my field research, I used different data collection strategies to ensure I did not miss any chances to gather information. My activities are outlined in the following table.

Project\development	Conception/planning	Implementation	Evaluation/perception
Rue de l’Oiseau Blanc		Conversations (mun)	Site visits (mun, res)
Rue Thénard		Site visits (mun, res),	
Falckensteinstraße	Interviews, documents	Site visits (mun, man, res), interviews	
Place Bellecour	Interviews, conversations (li-des, man, mun)		Observations (res), Interviews
Leibnizstraße	Interviews, conversations (man, mun, sci)		Observation, survey (res)
Montée du Boulevard	conversations (li-des, mun)	Observations, Conversations (li-des, mun, res)	
Altonaer Straße	Site visit (mun, man, li-d), Interviews		

Abbreviations: mun: municipality, man: manufacturer, li-des: lighting designer, sci: scientist, res: residents
Colours: first hand & second hand info

Table 3-3: Project-related data.

[104] Since they are also expensive (e.g. $2,000 and more) I only read the executive summaries and short versions.
[105] The content analysis includes 110 newspaper articles. The selection covers the publication period from 2005 to September 2012. The search was done via Lexisnexis®Wirtschaft in the German press with only the key words ‘Gaslight’ OR ‘gas lantern’ AND ‘Berlin’. There were no entries for articles that were published before 2005. The endpoint September 15, 2012 was pragmatically chosen. On that day, a pro-gaslight online petition ended and I had also given my presentation at the ESA conference. The coding process is explained in more detail in my article in the conference volume (Schulte-Römer, 2014a).

The Altonaer Straße project in Berlin was a special case. Here, I only attended the presentation of a new LED luminaire. The ephemeral character of the installation added another dimension—temporary versus permanent—to my contrastive analysis.

In addition to the project-based comparison, I also tested and compared my findings to what I learned about projects and lighting practices in other cities and countries. International events like *Strategies in Light Europe* (Munich), *Forum LED* (Lyon) and *Light + Building* (Frankfurt) and the LUCI conference series *City under Microscope* (Liège, Marseille and Rotterdam) offered me plenty of chances to talk to professionals, not only from Europe but also North America, Africa and Asia. Whenever I was invited to conferences as a speaker, I also used it as an opportunity to collect more data and information (NSR, 2011-10-19/20/21/22, 2012-03-27/28/29, 2013-10-30,31, 11-01,02). An invitation to a trade fair in Mexico in 2012 covered the cost for a stop-over in Los Angeles where I could study the city's comprehensive LED program and interviewed members of the L.A. Bureau of Street Lighting (OL & JQ, 2012-02-07). This experience proved very helpful later as it put my European findings into perspective.

3.3.3 Data analysis

As outlined above, my data analysis was inspired by situational analysis which draws on the toolkit of grounded theory methodology but places an emphasis on variation and differences. To make sense of my data and the 'messy' reality of early public LED installations, I engaged in coding, constant comparison and memoing.[106] Adele Clake's so-called mapping exercises helped me to sharpen my concepts and categories (see Figure 3-2).

'Coding means that we attach labels to segments of data that depict what each segment is about.' (Charmaz, 2006, p. 3). Grounded coding procedures vary in terms of their analytic function and level of abstraction. Open coding procedures allowed me to break up the data and to clarify who is doing what why when and where (see Mey & Mruck, 2010). The computer software Atlas.ti facilitated the process.[107] Since my aim was not to develop a grounded *theory,* I decided not to use more abstract coding procedures like axial or selective

[106] I wrote memos about participant observations, conceptual ideas and methodological challenges and problems.
[107] During my explorative research I also experimented with NVivo to analyse insights from fairs and festivals (Schulte-Römer, 2013b). Yet institutional path dependency led me back to Atlas.ti: the WZB holds a licence for the software. Furthermore, I had attended an introductory training at the WZB in 2009 and thus already knew the software.

coding (cf. Mey & Mruck, 2010) and went back to paper and pencil to work on my ‘thick’ situational analysis. To make this work more tangible I will give a few examples of both coding and mapping exercises and their results.

Open coding proved particularly useful for analysing and comparing newspaper articles (including images), EU documents and the most relevant expert interviews. Breaking up these different sources created a large number of coded pieces, which I then compared, reorganised and put together to create multi-perspectival versions of the situation. For instance, analysing an interview with a Lyonnais civil engineer drew my attention to his temporal sensitivity. ‘It is striking how often [he] uses the word ‘today’ (aujourd’hui) in the interview,’ I noted in a memo on experimental practice. The entire interview[108] nicely reflected the Lyon municipal engineers’ general preoccupation with the *kairos*, the right moment to apply LED light in their city. I could not detect a similar awareness and concern in Berlin.

The Berlin gaslight debate heightened my awareness of the public perception of public lights and, as a nice side effect, provided me with a rich data corpus of 110 newspaper articles for my above-mentioned content analysis. These included reports and opinion pieces as well as several pages of reader comments and responses. Comments were often tinted by emotion but also brought valuable details and critical questions to the fore.[109] Yet the differences in the language used by lighting experts and gaslight amateurs were even more interesting. While the first used vocabularies and arguments that referred to the cost and energy efficiency of lighting technology, ‘pro gaslight’ citizen initiatives highlighted the special nocturnal *atmosphere* of urban spaces: the soft glow of gas lanterns and the cultural identity of night-time West Berlin with its historical technological infrastructures. The open coding thus underlined not only the difference between technology users and light users but also their different realities: Those who use the *technology* are more affected by its usability and cost; those who use the *light* are affected by changes in the look and feel of urban spaces.

[108] The following passage shows what I mean in the original version (OV) : *« Le problème aujourd’hui c’est un petit peu une course où il faut acquérir une information, bien sur, pour savoir si la LED est performante, durable, ect. Mais la voir en temps et en heure et pas la voir avec un recul qui rend l’information inutile. Parce-ce si vous avez une information dix ans après sur un produit qui ne se fabrique plus elle devient inutile»* (DEP lighting engineer, 2012-01-06).

[109] Several comments questioned the official methods of evidence production and presentation. One heated online debate among commenters in a leftist Berlin newspaper, for instance, raised the issue of how to properly calculate the carbon footprint of gaslight in comparison to electric lighting (Schulte-Römer, 2010).

Another astonishing and theoretically challenging insight was revealed through *in vivo coding,*[110] namely the use of emotionalised, even violent language. For instance, the dismantling of the luminaires was described as 'carnage' and 'slaughter'. This did not at all match with my Lyon findings that 'citizens don't care' about public lighting and thus revealed an important difference regarding the public perception of lighting in the two cities.

Last but not least, *in vivo* codes also revealed some characteristics of the city lights phenomenon. For instance, the description of stray light as a 'cacophony' suggests that city lights cannot be reduced to their visual properties. Like sound, they cannot be analysed independently of other sensations (Schulte-Fortkamp, 2002) and might be best described in terms of urban atmospheres (G. Böhme, 1995).

The coding was accompanied by reiterative mapping exercises which helped me to analyse, elaborate and test the relationships between the coded pieces of the messy puzzle. Clarke's maps explicitly include discourses and imagery and thus offered an analytic tool that goes beyond a 'flat' description of observable material enactments and facts. Mapping thus allowed me to account for the immaterial, symbolic and imaginary links through which actors gave meaning to both public lights and the technological.

Clarke considers maps to be 'devices to materialize questions' (A. Clarke, 2005, p. 30). She distinguishes between three different types of maps: *Situational maps*, *social worlds/arenas maps*[111] and *positional maps*.[112] I only used the first of these three mapping exercises.

Situational maps come first. They 'layout the major human, nonhuman; discursive, and other elements in the research situation of concern and provoke analyses of relations among them' (A. E. Clarke, 2003, p. 554). The mapping begins with 'messy analyses', which show who and what is part of a situation. In a second stage, mapping exercises produce a 'relational analyses', which reveals existing and missing links between all entities in a situation.

[110] In vivo codes are named after and thus refer to expressions used by actors in the research field.
[111] *Social worlds/arenas maps* add a meso level to 'grounded theorizing after the post-modern turn' (A. Clarke, 2005, p. 110) Clarke describes it as 'the analysis of social/symbolic interaction. It is not high modern macro-level grand theoretical abstraction, ungrounded or inadequately grounded in empirical worlds. Rather, we can "see" collective action directly, empirically' (2005, p.110).
[112] *Positional map*s 'lay out the major positions taken, and not taken, in the data vis-à-vis particular discursive axes of and difference and variation, concern, and controversy surrounding complicated issues in the situation (A. E. Clarke, 2003, p. 554). They qualify social worlds/arena maps. In particular, they reveal who or what is not represented and 'positions that remain unarticulated' in the data (A. E. Clarke, 2003, p. 136).

In my project, the messy stocktaking exercise (see Figure 3-2) revealed the particularities of the Lyon and Berlin LED projects and the differences between their urban public lighting networks. In my relational analyses (see Figure 3-3) I not only mapped out links but also added qualitative information by drawing working relationships *in green* and problematic relationships *in red*. Figure 3-3 below illustrates the contrast between two extreme case studies: While in the Lyon case, the lighting designers who spoke for LED lighting successfully enrolled all relevant actors and things, the municipal spokespeople in Berlin were less successful.

Based on the mapping exercises for all six cases I realised that the Lyon civil engineers are better connected on a local and international basis than their colleagues in Berlin (see 5.4.1). The relational analyses also revealed the absence or only indirect nature of the relationship between the urban technology users and citizens.

Figure 3-2: Mapping exercise – first stage: 'Messy' situational analyses of the cases 6.1.1. and 6.2.1.

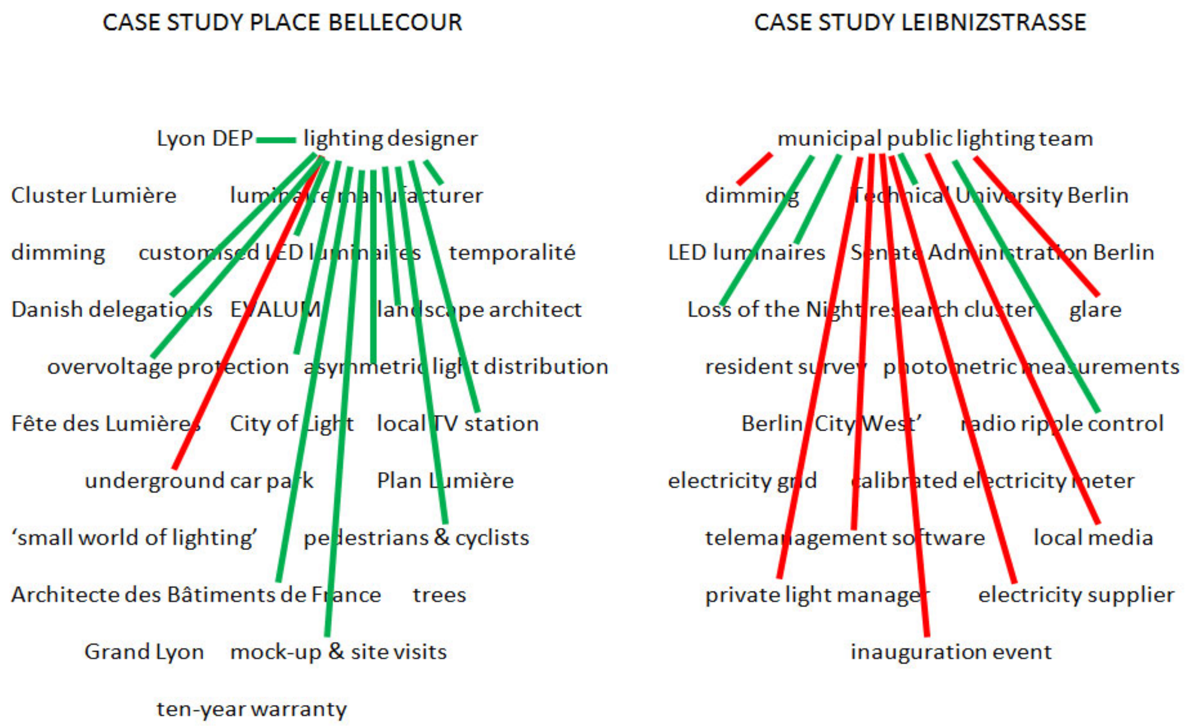

Figure 3-3: Mapping exercise – second stage: Relational analyses of the cases 6.1.1 and 6.2.1.

To conclude, situational mapping exercises account for and highlight not only the messiness of social interaction but also of the qualitative research process. As such, they are tools for making sense of complexity without oversimplifying it. Most importantly, they raise awareness of missing links and blind spots, non-existent relationships between people, things and issues that are in the situation but not enacted or evoked by key actors. This focus on absence and non-representation made situational analysis particularly salient for my research, as it filled the blind spots of the ANT approach.[113] In other words, it allowed me to see early public LED installations not only through the eyes of the 'spokespeople of innovation' but to also map out the perspectives of their silent observers.

[113] While ANT and its sensitivity to materiality inspired situational analysis, Clarke does not embrace the principle of generalised symmetry. She considers ANT 'both deeply provocative and productive' and stresses that adequate situational analysis '*must include the nonhuman explicitly and in considerable detail*.' (2003, p. 62).

3.3.4 Data preparation and presentation

The maps in this chapter not only illustrate my analytic procedures but also the data and how things and actors relate. Many previous versions of these maps have been discarded. The same applies to numerous notes and photographs I took during my field research.[114]

Image material was mostly collected to document events. Photographs of lighting technology and civil engineering work can make visible the invisible infrastructures and the taken-for-granted work of municipal public lighting services. I therefore heavily draw on photographs whenever I give spoken presentations and also in this work.

Interviews were mostly fully transcribed in their original languages (German, French, very few in English). The quotes presented in this work are translations. Unless stated otherwise, the translations from French into English were commissioned and done by David Pickering. To give the interested reader an impression of the orginal expression I added the original French and German interview passages in footnotes.

The memos I wrote throughout my research and data analysis are integrated in this text. Conversations and participant observations are cited as (NSR year-month-day)—my initials and the date of the observation. More information regarding the occasion of the participant observation or the conversation partner can be found in the list of primary data sources at the end of this work (see appendix 13).[115] Interviews are anonymised but I offer information about the function or profession of the expert and when the interview was held (see Table 3-2).

3.4 Methodological reflection

There are at least two good reasons to reflect on one's own role as a researcher. The first argument is deeply rooted in qualitative research practice and the research traditions I draw on—especially pragmatism and postmodern thinking. If we accept that realities and truth are not objective facts but the product of social practices and meaning making we also have to

[114] I have to self-critically admit that I did not apply the methodological toolkit of grounded theory rigorously enough, with the result that I had a lot of excess data.
[115] I also experimented with collecting my protocols and memos in a blog (http://urbanlighting.wordpress.com/) but gave up because the chronological order of the blog posts misrepresented my work flow.

accept that the position from which we perform our research can never be unbiased and therefore needs to be explicated.[116]

The second argument is a political one. Most research that accompanies an 'innovation in the making' is strategic or can be strategically exploited. It was therefore even more important to reflect on my role as a *participant* observer in the research field. To be honest, I could not escape these questions anyway. I constantly wondered about my role, whether my insatiable curiosity was appropriate and what I could give back to those I interviewed and observed.

3.4.1 Multiple identities and learning to see

George E. Marcus describes multi-sited ethnographic research in a way I can identify with:

> 'In conducting multi-sited research, one finds oneself with all sorts of crosscutting and contradictory personal commitments. These conflicts are resolved, perhaps ambivalently, not by refuge in being a detached anthropological scholar, but in being a sort of ethnographer-activist, renegotiating identities in different sites as one learns more about a slice of the world system' (Marcus, 1995a, p. 113).

My identity as a sociologist was anything but clear, neither to myself nor to others. I was a German in France, a social scientist in the lighting technology colloquium, a PhD student of 'what is it exactly that you are doing?' More than once I was mistaken for a lighting designer. The funniest welcome I heard regarding my presence was: 'I don't know who you are but you pop up everywhere'. Equally bittersweet, a lighting designer introduced me to her colleagues as 'the researcher who is studying us'. These comments nicely represent the strange familiarity of the participant observer. But they also made me feel uncomfortable. I therefore tried to make my role more tangible by discussing my interests and ideas more openly. In this respect, it also helped that I regularly presented my findings in conferences in the field. Sharing ideas also had the nice side-effect that it helped me to test preliminary results.

Social identity was one issue to think about, bodily capacities were another. Lars Frers addresses this blind spot in the literature on qualitative research methods (2012). He argues that although all data collection in the field first and foremost depends on the researchers'

[116] Situational analysis not only acknowledges this bias but embraces it by considering the researcher her/himself as the most important research instrument (A. Clarke, 2005). In a less postmodern way, this is also true for GTM, which offers a well-defined guideline for the research process but no rigid ready-made framework. Mey and Mruck describe it therefore as 'freedom of research' that empowers and encourages the researcher to trust her/his scientific intelligence (Mey & Mruck, 2010, p. 624).

senses—and only then on her/his sensitivity—the researcher's corporal embeddedness is rarely reflected upon.[117] When I started my research I was blind, technically speaking, as I could not see what light professional saw. In a memo titled 'learning to see' I noted in June 2012:

> 'Beautiful gaslight: Yesterday I went home on my bike and, for the first time, I saw how specially the gas lighting illuminates my neighbourhood. The lanterns stood in a row, producing a chain of torch-like light points. It was already becoming morning and the yellowish glow created a nice contrast against the dark blue sky. I think it is quite remarkable that I can rejoice at the sight of gas lanterns today. Two years ago, I could not even distinguish them from electric lighting. […] I remember asking a light technician how I could see or tell the difference. He said that the difference between gas and electricity was obvious.'

The knowledge I gained during my research has changed my vision and my perception of light and lighting technology remarkably. Today, I cannot help noticing luminaire designs and light sources—sodium high pressure or sodium low pressure, fluorescent tubes, gas sockets or LEDs—wherever I go at night.[118] Thus, I have not only developed a researcher identity but also have become some sort of light freak. But I am not mentioning this almost auto-ethnographic reflection on my new sensory capacities just for fun. It also had important analytical implications, as it helped me to better understand the difference between expert and lay perspectives on urban lighting.

Finally, my 'multi-sited activism' also involved shifting between strange and familiar worlds. As Knoblauch argues, sociological ethnographies are, in contrast to ethnological ethnographies, performed in the researcher's own sociocultural environment (2001, p. 124). However, although I have lived in Berlin since the year 2000 and was familiar with the city's look and feel, its world of lighting was strange to me. On the other hand everybody who has lived and moved around in Berlin knows that every *Kiez* (neighbourhood) has its own look and feel. Unavoidably, I lacked this intuitive insider knowledge in Lyon. At first, my bias worried me but then I found that I could use it to my advantage: Both my new sense for light

[117] Frers also points to the analytic bias for our visual sense which is reflected in the term 'participant *observation*' (2012, pp. 214-215). The geographer and phenomenologist Lars Frers addresses this problem of the ethnographers' bounded attention and explores how the tensions between proximity and distance, mixed reality ('*Gemenge'*) and analysis, presence and recording can be made productive for ethnographic research (2012).

[118] A key moment in my light research career occurred when I was sitting in the S-Bahn one afternoon. I looked out at Bahnhof Zoo, saw and pointed at a street luminaire to show my friend the 'interesting street lights' and felt like nerd afterwards.

and my Lyon experience made me recognise things that I had previously overlooked.[119] For instance, I had never noticed the low light levels in Berlin while I lived there. Coming back from bright Lyon, the difference struck me and I had to readapt to the dark streets and their problems for cyclists. In contrast, cycling in Lyon made me recognise the car-friendliness of the city, which is a relevant information since the car-oriented urban planning paradigm has shaped the public lights of our cities (see 4.3.3 and appendix 9).

Today, I experience *both* cities differently. Lyon has become more familiar and Berlin stranger. My image of both cities formed through my personal and ethnographic engagement with nocturnal urban spaces and conversations with light experts. In line with my 'messy' methodological approach, these images resemble a Picasso portrait more than a Dutch landscape painting.

3.4.2 Lost in translation?

Language was another challenge in the double sense of spoken and expert language. When I started my research stay in Lyon my French was far from perfect.[120] In the first week, I went to some 'research blind dates' because I had not quite understood on the phone what the experts were up to. Analysing my field notes I also found that I had more detailed and also more confusing information about Berlin than about Lyon. I have not concealed this bias. The reader might find that there are more direct quotations from conversations with German actors, which results from the fact that my field notes from Berlin contain more memorised direct speech. In France, I rather recollected conversations in English and therefore find less

[119] My first encounter with Lyon dates back to a time when I was still involved in the world of Berlin off-theatre and learnt that Lyon had an equally vibrant theatre scene. Yet although I was already on my sociological light mission when I first visited Lyon in December 2010, my love of theatre also affected the way in which I encountered the city in my nocturnal ethnographic journeys. Because Lyon's theatres are scattered all over the place, whenever I ventured to see a play I found myself cycling passing nocturnal urban spaces I would not have visited otherwise. It is thus no exaggeration to say that the Lyon performing arts scene shaped my sense of the night-time city—as whole connected unity and as an assemblage of different quarters with distinct nocturnal atmospheres.

[120] I studied French as third language for five years at school. In my first semester at Humboldt-University Berlin I attended a conversation course focusing on the European Union. After ten years of abstinence, my French skills clearly needed an update. So I participated in a French conversation course at the Technical University Berlin during 2011 summer semester. It was a lucky coincidence that the topics discussed in this class were architecture, urban planning and urbanism.

direct quotations in French in my field notes.[121] It thus cannot be denied that my command of the French language affected my research practice and data collection.

However, I also developed effective strategies to minimise the language bias. Since I found it difficult to understand people on the phone, I met them in person. Only one interview was held on the phone—in English. Furthermore, the interview recordings show that my questions were not always precise but still triggered the answers I was looking for. Sometimes, vague questions even prompted people to come up with relevant issues that I had not even thought of. I recall only one case where my language skills negatively affected the interview situation: The interviewee was not very talkative and I lacked the rhetorical skills to break through his reserve.

Another and sometimes far more confusing language difficulty and challenge was to enter the world of *illuminance/éclairement/Beleuchtungsstärke* and *luminance/luminance/Leuchtdichte*. In this case, the world-wide web saved me from being lost in translation.

3.4.3 Scaling-up and down

As I come to the end of this chapter, I once again return to the question of how to make sense of 'the global' by focusing on 'the local'. As Marcus suggests, such scaling-up and down can itself be understood as a knowledge-based and hence cultural practice:

> 'Sorting out the relationships of the local to the global is a salient and pervasive form of local knowledge that remains to be recognized and discovered in the embedded idioms and discourses of any contemporary site that can be defined by its relationship to the world system' (Marcus, 1995a, p. 112).

Accordingly, we can assume that my social-scientific perspective on 'the global' is not the same as a lighting engineer's perception of the LED development and light-related discourses or policies on the global scale. This also explains why my following account of the LED innovation process differs from the innovators' perspective. Unlike market reports or roadmaps, the following chapter contains very little technical and financial figures and

[121] Another reason for this slight imbalance is that I could not follow every little thread in group conversations, either because I did not understand what was discussed or because I was not spontaneous enough to interrupt and follow-up on tiny remarks and potentially valuable information. I particularly recall one occasion with the DEP planning director who picked up the phone in my presence and entered a passionate discussion about something related to the 'marché public'. Not knowing that they were quarrelling about 'public procurement' procedures I missed the opportunity to ask further questions.

numbers. Instead, my account draws together what I learned about the innovation and the technology during my multi-sited ethnographic research, during conferences and in the installation sites. Similarly, my perspectives on Lyon and Berlin draw on first-hand information and participant observations. Chapter 4 and 5 should therefore not be misunderstood as stand-alone analyses of innovation in public lighting or urban ethnographies of Berlin or Lyon at night. Instead, they offer the reader an introductory overview, which is comprehensive in the sense that it offers all the information s/he needs to understand the six urban LED situations described in chapter 6. Drawn together at one glance in a messy map (Figure 3-4), this information to follow can be visualised as a cloud of actors, artefacts and issues that were enacted and evoked in six early public LED installations.

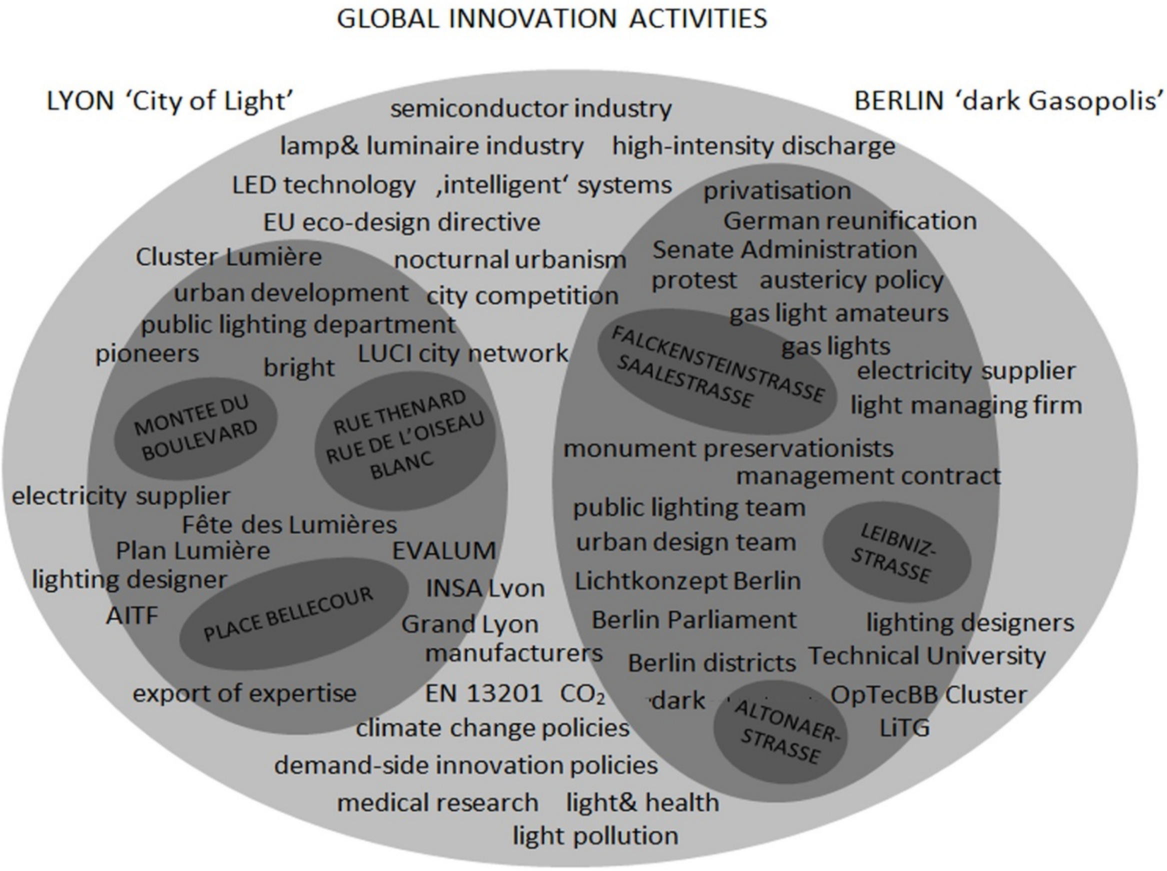

Figure 3-4: Messy map showing six LED situations in Lyon and Berlin and their different scales.

4. LED technology and other developments on the global scale

The advent of LED technology is not the only current new development in public lighting, but it surely receives the most attention. LED products are designed and destined to 'replace every other form of lighting, including the incandescant light bulb and the fluorescent tube, in our homes, offices, and everywhere else besides.' (Johnstone, 2007, p. 9). In 2005, Businessweek reported that the LED 'is poised to turn Thomas Edison's light bulbs into museum pieces' (Port, 2005-05-22). A Wikipedia article on 'disruptive innovation' puts LEDs in line with the telephone, the automobile and the digital camera.[122]

The tiny light emitters nourish high hopes but also legitimate concerns. Due to their great and growing luminous efficacy, LEDs are considered an energy efficient alternative to conventional light sources, including high intensity discharge lamps (HID), which are widely used in public lighting.[123] The European Commission expects that LED lighting can 'make our cities "greener" by saving up to 70 of lighting energy and reducing costs compared to existing lighting infrastructures' (European Commission, 2013-06, p. 5). But at this moment in 2014, the future of LED technology in public lighting is still unwritten. Technological development is ongoing, technological paths are still being created. The traditional European lighting industry has to keep up with the fast-moving global semiconductor industry. Technology users see themselves confronted with a promising, but also challenging, electronic light source as LED products raise questions and uncertainties concerning their quality, compatibiliy and operability.

The current relevance and open future of the innovation process makes it an interesting but also elusive subject. In this chapter, I will first introduce the technology and offer a snapshot of its technological development (4.1). I will then describe technology-related issues, the industrial challenges, professional perspectives and political incentives that were relevant in 2011 and 2012, when the first street LED luminaires were installed in Lyon and Berlin (4.2). As outlined above, my account is based on empirical findings rather than secondary sources

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[122] http://en.wikipedia.org/wiki/Disruptive_innovation, access date: 2012-09-28.

[123] The theoretical limit of the luminous efficacy of white LEDs seems to lie between 250-380 lumen/Watt 'depending on spectral extent and corresponding "whiteness."' (Murphy Jr, 2012, p. 8). Please note that this value concerns LED packages, that is, the basic LED units that are built into luminaires. The luminous efficacy of a retrofit LED light bulb is much lower since the ratio of energy input and light output is reduced through lens systems and the electronic components like the drivers of a lamp or luminaire. In addition to that, there are photometrical issues that make the comparison even more complicated as will be discussed later in this work. http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/led_energy_efficiency.pdf, access 2014-07-03.

and focuses on innovation activities, opportunities and uncertainties, rather than technical and financial questions. The focus is limited to street lighting and not LEDs in general. Finally, I will sketch out other developments that accompany the 'revolution in lighting' (4.3). Together, these dynamics constitute a *new situation*, in which public lighting is subject to change, rediscovery and critical reflection on a global scale.

4.1 The 21st century's revolution in lighting

Technological breakthroughs in artificial lighting occur at astonishingly regular intervals. Gas lighting was introduced at the end of the 18th century and followed by electric lighting at the end of the 19th century (see appendix 9). Another hundred years later, LED lighting entered the scene. The innovators raise high expections:

> 'LEDs are bringing a lighting revolution to our cities not seen since the days of Thomas Edison. The quantum dynamics that create light in the LED semiconductor represent as much of a technology step change as the move from candles to incandescent lamps in the 19th century' (The Climate Group, 2012-06, p. 6).[124]

Today, the trend towards cheaper and more performant LED sources is unbroken. The promise of the 'holy grail of lighting' is still alive and closer than ever: 'a 200lm/W white light source two times more efficient than fluorescent lamps, and ten times more efficient than incandescent lamps' (Roland Haitz et al., 1999, p. 1).[125] But LEDs are not only energy-efficient. They are also long-lasting, flexible in light distribution and dimmable. In laboratory stress tests they reach operating times considerably greater than 50,000 hours and thus outperform conventional light sources.[126] In the case of public lighting, where the annual operation time is around 4,000 hours, this means that LEDs might last 12 years under

[124] This is how the 'LED revolution' is described in a report with the subtitle 'The rise of LEDs and what it means for cities', which was published in 2012 by an 'international coalition of some of the world's most powerful leaders' and sponsored by the electronic and LED-selling company Philips.

[125] For a comparison, the efficacy of high-intensity discharge light sources like high-pressure sodium lamps (HPS) lies around 150 lm/W (Licht.de, 2010).

[126] For instance, high-intensity discharge lamps, which are still much cheaper than LEDs and can compete with LED sources in terms of efficiency, only have about half the average lifetime or less. In the case of the incandescent light bulb the lamp industry is said to have deliberately limited its lifetime to 1000 running hours. Such forms of standardising the failure of products are also described as planned obsolescence. See also: http://www.sueddeutsche.de/wirtschaft/geplanter-verschleiss-von-produkten-ploetzlicher-tod-der-gluehbirne-1.1660236, last access 2014-08-10. Other sources state that the lifetime of light bulbs is 3,000 hours (The Climate Group, 2012-06, p. 55). Since they are not used in public lighting this problem is less relevant for this study.

favourable climate conditions, which can reduce the maintenance cost and total cost of ownership. Furthermore, LEDs can be dimmed and have a more flexible light distribution. It is suggested that the energy consumption for public lighting within the EU could be cut by 64 per cent if cities and communes implemented 'intelligent' lighting systems.[127] In its most radical consequence, the 'revolution in lighting' thus means the digitalisation and customisation of public lighting. It means a shift from electric to electronic lighting and the introduction of adaptive control systems. So let us have closer look on the technology, techniques and technological artefacts that are needed for this 'revolution'.

4.1.1 LED light: Nano-technology for large technological systems

One LED alone does not make a luminaire. To be more precise, it is helpful to make some distinctions. In the following I will refer to *LED technology* as a conglomerate of materials, production techniques and scientific knowledge.[128] *LED chips* refer to the point-like light source and *LED modules* to arrangements of several chips, often in standardised forms, that are built into luminaires. *LED luminaires* are technological artefacts made of different components. Finally, *LED lighting* refers to working configurations of old and new components, including the small and also the larger technological systems that constitute urban public lighting infrastructures (see Figure 4-1 below).

At the core, the 'revolution in lighting' is nanotechnological and electronic. The new light shines when 'tiny specks' of semiconductor material are exposed to a low voltage (Johnstone, 2007). In contrast to incandescent light sources which emit light through heat generation, LED light is produced through electronic excitation and the emission of photons, or more precisely, solid-state electroluminescence, which is why LEDs are also more broadly referred to as solid-state lighting (SSL).[129]

SSL is high-tech. LED luminaires consist of various tiny and larger components. The production of the crystalline nano-structures that will emit the light starts in the cleanrooms. It involves expensive and sophisticated laboratory equipment and procedures and takes place on

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[127] http://energiesparendeaussenbeleuchtung.wordpress.com/, *ESOLi* (Energy Saving Outdoor Lighting), last access 2014-08-10.

[128] See Rammert (1999) for a sociological definition of the term 'technology' in German and English.

[129] Solid-state lighting comprises not only LEDs but also organic light-emitting diodes (OLEDs) and polymer light-emitting diodes (PLED). OLEDs are very thin and soft-glowing light sources. At the present moment, they are still expensive and less developed than LEDs but already very promising for backlighting, innovative two-dimensional lighting designs and the illumination of architectural facades.

a nano-scale, invisible to the naked eye (Johnstone, 2007, p. 73). In a nutshell, the 'tiny specks' are pieces of so-called wafers that consist of layered semiconductor materials.[130] These layers are only a few atoms thick. In a complicated process, one is positively charged with fewer electrons and the other layer negatively charged with free-moving electrons. If a low-voltage electric current flows through the diode (in only one direction) and excites the free electrons, they jump from the negative to the positive layer at the so-called p-n junction. The more electrons cross that boundary, the brighter the light. The wave length of the emitted light is determined by the energy gap or so-called 'band gap' of the semiconductor (Licht.de, 2010; The Climate Group, 2012-06).

To produce an LED chip, the wafers are then broken into tiny pieces and packaged. Packaging means that the specks are equipped with an anode and cathode and embedded in a heat sink that keeps the semi-conductor crystals cool.[131] They are also covered with an optical layer that bundles and directs the light. Yet the light quality and characteristics of diodes from the same wafer can vary considerably. Since the microscopic impurities in the semiconductor crystals are not evenly distributed, the wafer fragments emit light of varying quality and colour temperatures. Therefore, the LEDs need to be sorted in a tedious selection process. The selection process is called binning and produces a lot of junk.[132]

There are no compound semi-conductor materials that emit white light since white is a mixture of colours. In the case of LEDs this is a problem. Unlike conventional light sources, electroluminescent light has a specific wavelength which is determined by the semiconductors' bandgaps and the discrete energy levels that are set free when the electrons jump. The most common method to produce a white-glowing LED source is to use a blue diode and cover it with a phosphorus coating which converts the blue into white light. This is why many LED chips look like egg yolks. The effect is called photoluminescence. Another method is additive colour mixing: The beams of red, green and blue (RGB) diodes are

[130] Wafers are made of a silicon or sapphire-on-silicon layer that is specially treated and thereby negatively charged and a layer of another compound semiconductor material, for instance gallium arsenide (GaAs), gallium phosphide (GaP), or gallium arsenide phosphide (GaAsP).

[131] Since heat reduces their light output and lifetime and can change their colour, one difficulty lies in finding the right equilibrium between light output and thermal management. Another challenge for basic research is to improve and find new compound materials to make LEDs even more efficient (Tsao, 2010).

[132] Since the nano-differences in the chips are invisible to the naked eye, every wafer piece is tested individually so that the diodes can be sorted according to their light output and quality. LED producer world-wide work on optimising the binning procedures in order to reduce the waste and render the production of LEDs more efficient.

combined so that their wavelengths mix to create white (Licht.de, 2010). A third method is a hybrid of colour mixing and conversion.[133]

In luminaires we find LED chips in modularised forms, in different sizes and with different colours and light outputs. The light is either distributed through lenses that cover the module or through reflectors inside the luminaire, which are particularly important in the case of LED lighting. Conventional light sources shine more or less in all directions unless they are shielded on one side through a reflector, luminaire case or lamp shade. In contrast, LEDs emit pointed bundles of directed and strong light. We all know the effect: Looking into the beam of a flashlight in the dark or into a laser has a blinding effect. The same applies to LED, which presents a challenge for luminaire manufacturers. Glare is something that is absolutely undesirable in street lighting, because it increases the traffic danger by blinding drivers instead of improving visibility and safety on the street. The more powerful the punctual LED light source, the greater the risk that it will produce glare. Optical lenses that diffuse the beam, or indirect lighting systems with reflectors, are used to remedy this problem. Both techniques reduce the light output and are therefore a compromise in terms of efficacy.

Another important component in LED luminaires it the socalled LED driver which ensures that the electric power supply is perfectly adjusted to the semi-conductor chip: It transforms alternate current (AC) into direct current (DC) and prevents the voltage fluctuations in the larger electricity grid from destroying the LEDs. Furthermore, thermal management devices are required since LEDs are very sensitive to heat and fail or lose their power if it gets too warm. Although it is true that they produce much less heat than an incandescant light source,[134] LEDs do warm up and so do their drivers. In luminaires, heat is diverted either through lamellar structures, special coatings or even energy consuming fans inside the case.

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[133] For a short explanation with graphic description see: http://energy.gov/eere/ssl/led-basics or: http://www.osram.com/osram_com/news-and-knowledge/led-home/professional-knowledge/led-basics/light-colors/index.jsp, last access 2014-08-01.

[134] Light bulbs emit only about 15 per cent of their energy in the form of visible light. The Climate Group's report offers a short and comprehensible explanation: 'In the incandescent lamp, a metal such as tungsten formed into a thin wire resists electrons flowing through it, thus causing friction and heat. The metal glows as the cramped electrons bounce around and shed some of their excess energy as photons. The incandescent lamp is essentially a heat source—light is merely a byproduct representing only 10% to 25% of the energy consumed, 10 - 15 lumens per watt' (2012-06, p. 55).

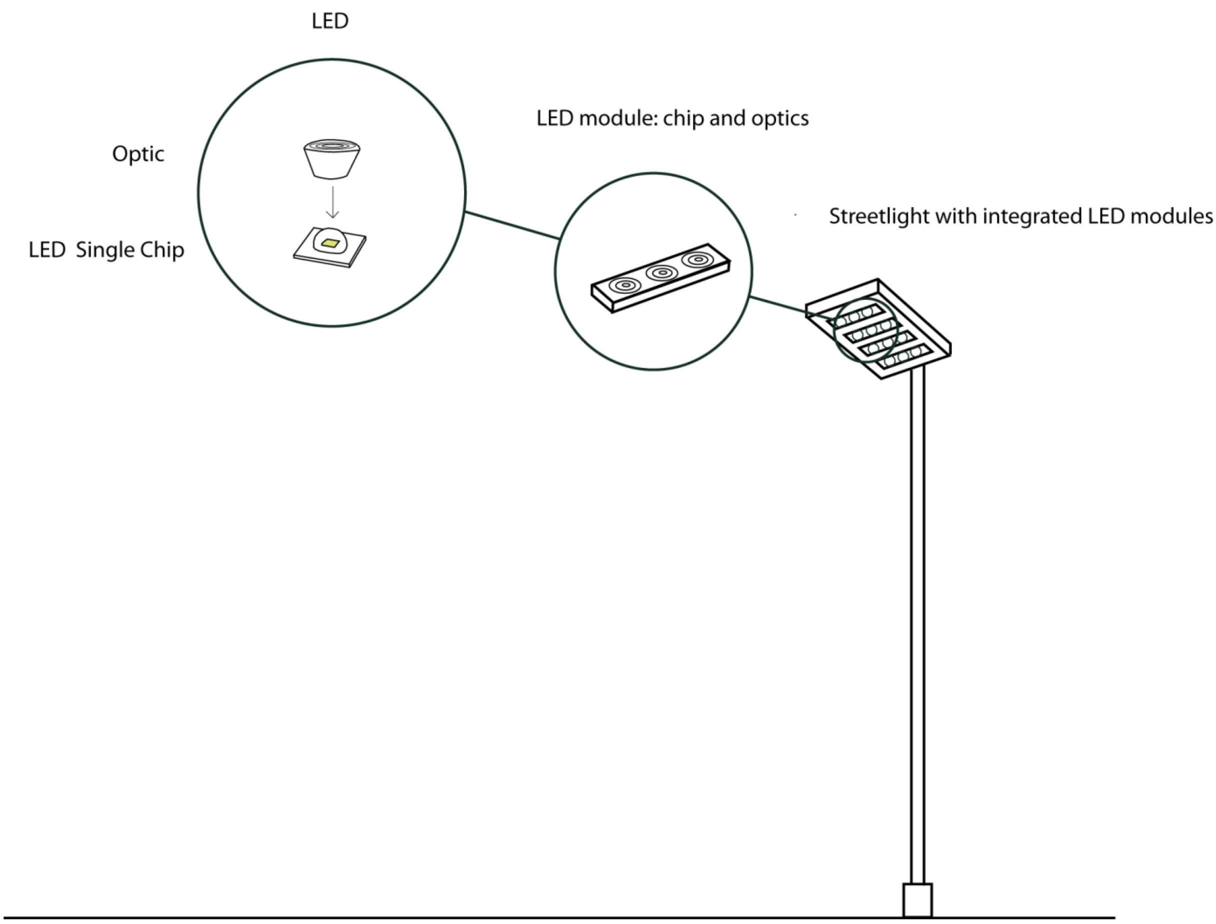

Figure 4-1: An LED chip in a LED module in a streetlight on a pole (CC).

But the story does not end with the LED module, driver, thermal management and optical system in a luminaire case. Before LED lighting illuminates urban streets, luminaires are mounted to existing or new poles and connected to larger technical systems, such as energy grids and remote control systems that switch the lights on at dusk and off again at dawn. As the case studies in chapter 6 show, these existing urban infrastructures vary across cities. After all, these so-called ‘large technological systems’ (cf. Thomas P. Hughes, 1987) evolved a hundred years ago, when the first electric lights were installed (see 9.3). While electric lighting required the establishment of a new power supply system, the new electronic street lights now call for digital and intelligent lighting control. As we will see in the following sections, this related innovation process, which concerns urban infrastructures of cities, has only just begun in European cities. Although the first LEDs were presented half a century ago, they are still a quite new phenomenon in public lighting.

4.1.2 Technological breakthroughs: From red, to blue, to white

The physical effect of electroluminiscence has been known since 1907. The discovery of LEDs was a byproduct of the development of transitors and laser research. The first red-glowing LED was presented in 1962 by the electrical engineer Nick Holonyak and his team at General Electrics (GE). In 1963, the author of an article in the U.S. Reader's Digest already suggested that these 'dramatic laser discoveries' might render conventional electric light sources obsolete: 'The lamp of the future may be a speck of metal the size of a pencil-point which will be practically indestructible, will never burn out, and will convert at least ten times as much current into light as does today's bulb' (Manchester, 1963, p. 100). In the same article, the inventor Holonyak suggested that 'there is a strong possibility of developing the laser as a practical light source'. Yet he also stated that in order to develop such white LEDs for general lighting, 'much more experimental work must be done, and it might be ten years or more before such a lamp could be ready for use' (Manchester, 1963, p. 100). In fact, it took almost 50 years before LED products were bright enough and, above all, white enough to illuminate streets and public spaces. On the other hand, the new technology has met and even exceeded scientific and commercial expectations in terms of performance and light quality.

Althouth the first red glowing diode and today's high-brightness LED modules are based on the same principle of electroluminiscence, they are hardly comparable in terms of uses. The weak-glowing, red—and later also yellow and orange—early diodes became known in public as little control lights. In the 1990s, LEDs first entered the streets as traffic signals, colourful commercial and decorative lighting, for instance at Christmas and media facades,[135] and car lights (Zukauskas, Shur, & Gaska, 2002, p. xi). Yet as long as high-brightness LEDs had not yet been developed, the technology was unsuitable for general lighting.

[135] These multiple uses of LED technology in cities also show that my focus on street lighting only covers one particular aspect of the wider topic of city lights as a cultural, social and political phenomenon. Commercial LED media facades, for instance, can cause light controversies and raise regulatory as well as urban design questions (Hasse, 2007c; Krause, 2015). From a cultural and aesthetic point of view, LEDs transform the look and feel of urban spaces. Tiny as they are, they allow designers to create high-resolution displays. OLEDs, the next revolution in lighting, will add another new experience when facades will be transformed into soft glowing surfaces that illuminate spaces homogeneously without hard contrasts or shadows (for a cultural reflection on shadows see Tanizaki, 1988 [1933]).

Year	Emitted colours (wave lengths)	Semi-conductor material	Abbreviation
1962	Red (630-660nm)	Aluminium Gallium Arsenide	AlGaAs
1970s	Orange (605-620nm)	Aluminium Indium Gallium Phosphide &	AlInGaP
1970s	Yellow (585-595nm)	Gallium Arsenide Phosphide	GaAsP
1980s	Green550-570nm)	(Aluminium) Gallium Phosphide	AlGaP, GaP
1990s	Blue (430-505nm)	Gallium Indium Nitride	GaN

Table 4-1: From red to blue light-emitting diodes.[136]

The problem was that no blue LED had yet been developed. Yet as outlined above, the blue light was necessary for mixing or converting LED light into white light. The breakthrough was achieved in 1993 by the Japanese physicist Shuji Nakamura in his laboratories at Nichia (Johnstone, 2007). Using the compound semi-conductor gallium nitride (GaN), Nakamura succeeded in producing the long awaited bright blue LED.

The first white LEDs, which converted blue electroluminescent lighting into white, were presented in 1995 (Licht.de, 2010). They gave a cool-white light and were on the market in 1997. The first warm-white LEDs were commercialized in 2005 (Roland Haitz & Tsao, 2011).

With this technological breakthrough, the innovation entered a new stage. LED lighting became an issue on the climate-political agenda. In 1999, a team of researchers published an influential paper in which the authors made 'the case for a national research program on semiconductor lighting' (Roland Haitz et al., 1999). The authors suggested that the use of LEDs for general lighting could reduce worldwide energy consumption for general artificial lighting by more than 50 per cent and decrease the global energy consumption by at least 10 per cent and called for a 'concerted national effort' (Roland Haitz et al., 1999, p. 1). The paper became influential, not only because it raised high hopes and outlined technical and marketisation problems of SSL, but also because it contained a cost-LED-performance prognosis, which made the expectations regarding LED lighting more tangible.[137]

Drawing on existing market data, one of the authors, Roland Haitz, mapped out the past development of LED sources and projected it into the future. Based on the assumption that the performance of red LEDs could be a good predictor for white LEDs (2011, p. 18), Haitz showed in a 'Moore's-law-like fashion' that the light flux of LEDs (lm/W) had increased 30

[136] Source: http://www.electronics-tutorials.ws/diode/diode_8.html, last access 2014-09-20 and Licht.de (2010).
[137] See van Lente (2012) for a discussion of the performative potentials of foresight and prognoses that function like self-fulfilling prophecies.

times per decade, while their price[138] had decreased 10 times per decade. He further suggested that both developments would continue at this rate (Roland Haitz et al., 1999, p. 5).[139] The prognosis became known as 'Haitz's law' and was updated and corrected in 2003 (Figure 4-2). Looking back, the authors explained in 2011: 'The resulting graph, published in 2003 […] represented 35 years of red lm/lamp and 30 years of red $/lm data'. While the trend curve for the cost development remained unchanged, the slope for the light flux development of red LEDs was corrected 'from 30x/decade in the 1999 graph to 20x/decade' in the 2003 graph. In 2010, cool-white LEDs (5000 to 8000 Kelvin) were integrated into the calculation and showed an even steeper curve development in light output (2011, p. 18).

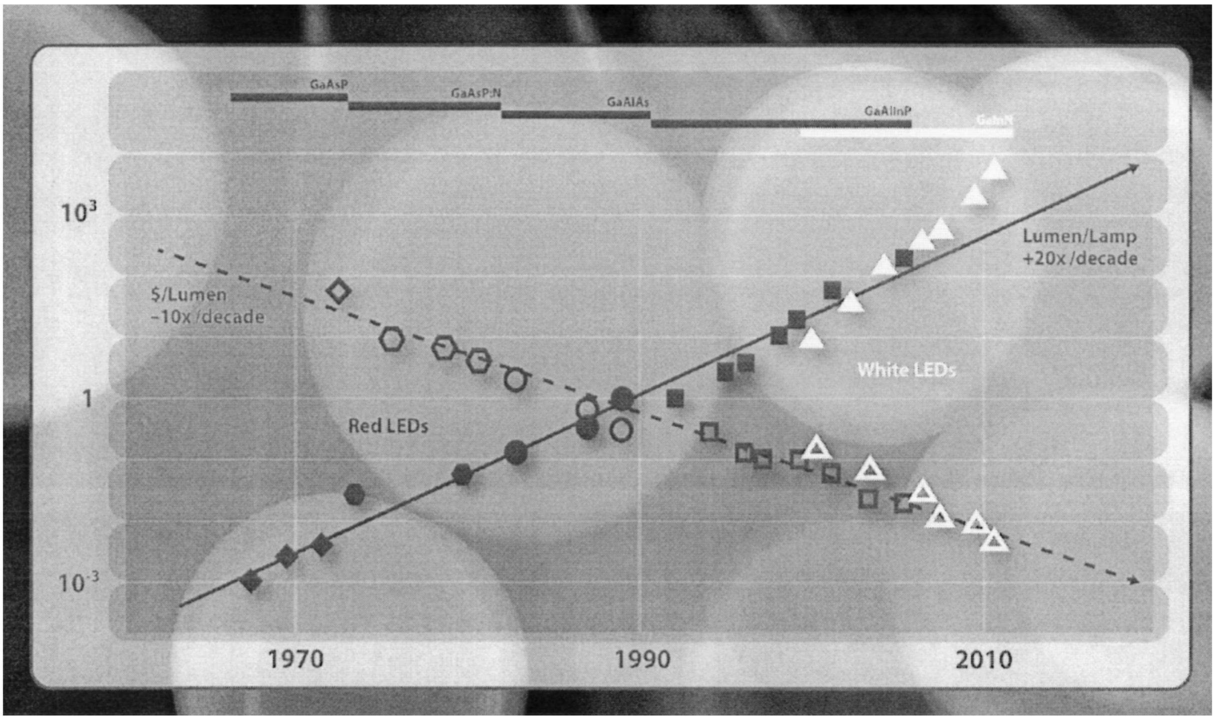

Figure 4-2: The development of red and white LED outputs and cost (Haitz, 2011, cover page).

The prognosis proved astonishingly correct (cf. Consée, 2011-04-14). Meanwhile, high-brightness LEDs have long cleared the 100lm/W hurdle and there is more potential. Basic research is still revealing new and better compound semi-conductor materials. The industry is

[138] This refers to the prices charged by LED suppliers and paid by luminaire manufacturers and other *Original Equipment Manufacturer* (OEMs).
[139] For a critical discussion of the analogy between Moore's law for the semi-conductor industry and Haitz' law for SSL see (Roland Haitz & Tsao, 2011). The authors explain that the LED development differs from that of semiconductors despite a similar 'see-saw-dynamic'. There is a *physical* limit to the maximal efficacy of light sources which does not apply to semi-conductors in general. Furthermore, they argue that there is an insatiable need for faster computer chips but a finite need for brighter light. Too bright lights are perceived as uncomfortable (2011, p. 20).

still exploring better and cheaper production techniques.[140] At the same time, a new industrial field has emerged around SSL, including political programmes, and new institutions for market regulation, observation and information. Around the year 2000, specialised media and market information companies began to systematically report on and organise events around SSL.[141] Furthermore, SSL made its way onto the agenda of innovation policy makers worldwide. Since 2003, the U.S. Department of Energy (DOE) and its agencies actively support SSL research and deployment in the USA.[142] In Europe, the European Commission supports research and development in Photonics under the umbrella of its Digital Agenda[143]—not least in order to help European industries keep up with research and development in Asia (cf. Photonics21, 2010). The industrial challenge is outlined in the following section.

4.2 A disruptive innovation

Ambiguities are a characteristic feature of innovations. While the energy-saving potential of LED lighting is beyond doubt and the technology is still improving, the realisation of this potential and promise requires both LED producers and users to adapt to the innovation. From the perspective of the European lighting industry, LED lighting is a model case of a disruptive innovation (Thomond et al., 2003). Such innovations confront established firms with the dilemma of having to invest in new technologies that do not at first meet the key performance criteria of the mainstream customers (see appendix 10.1, Clayton M Christensen & Bower, 1996). LEDs, for instance, have long been out of the question for general lighting, since their light was neither white nor bright enough. They were first used as coloured indicator lights, for display backlighting, in traffic signals, and in decorative and architectural lighting. Meanwhile, LEDs have developed further and outgrown their niches. Within the last ten years, the light output and quality of LED luminaires has become good enough for street lighting and they are expected to soon outperform high-intensity discharge technology, which used to be the most promising and efficient technology before LEDs entered the scene and manufacturers reallocated their R&D budgets. Thus, LED lighting changes the 'technological

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[140] These include experiments with different semiconductor materials for the production of more robust wafers or the development of AC current LEDs (cf. Schulte-Römer, 2013f).
[141] One example is the PennWell Corporation launched LED Magazine and the 'Strategies in Light' conference series, which is regularly held not only in the U.S. but also in Asia and Europe. These formats offer potential investors and business partners the opportunity to connect and stay up to date (NSR, 2012-09).
[142] See http://energy.gov/eere/ssl/why-ssl, last access 2014-08-20.
[143] See http://cordis.europa.eu/fp7/ict/photonics/digitalagenda-and-ssl_en.html, last access 2014-08-20.

paradigm' in general lighting (Dosi, 1982) and thereby confronts the incumbent firms and so-called mainstream customers—such as public lighting services—with major challenges.

High-tech production processes replace low-tech manufacturing. The fast-moving semi-conductor industry disrupts the highly standardised and traditional lighting industry as LED products could jeopardise the replacement business with conventional light sources like incandescent light bulbs, high intensity discharge lamps or fluorescent. Finally, the 'disruptive innovation' offers new possibilities that can only be fully realised if lighting practices and existing urban infrastructures are also modified: While 'intelligent' lighting systems offer the greatest energy-saving potential, they also demand from their users the greatest willingness to *innovate in public* and to adapt to the new light.

4.2.1 The producer perspective: Globalisation and acceleration

At the end of July 2014, the lighting industry made headlines in the German media with bad news. Osram, the traditional German lamp manufacturer, and formerly part of Siemens, had announced it would cut almost a quarter of its jobs until 2017. The national newspaper *Süddeutsche Zeitung* explains the reason: The business with traditional illuminants is declining faster than expected. Energy-efficient LED lamps have become significantly cheaper within the last months. Yet LEDs are primarily produced in Asia and not in Europa (Busse & Giesen, 2014-07-31, p. 2).[144]

'Made in Asia' and 'within months'—indeed, globalisation and acceleration are the keywords that best describe what troubles the European lighting industry. The transition in the lighting market is reflected in a number of company divisions and mergers. The question of who will survive the disruptive innovation process is still open. New market entrants from adjacent fields like the semi-conductor and electronic industries are challenging the 'comfortable oligopoly' of European lamp and luminaire manufacturers (NSR, 2012-09; Schulte-Römer, 2013f). New players, especially in Asia, are setting the pace and, more importantly, the prices. The value chain of LED products has spread across continents. LED chips might be produced in Korean laboratories, LED modules and luminaires designed in the Netherlands and produced in China and then tested and certified in France or Germany. European

[144] OV: *„Das Geschäft mit traditionellen Leuchtmitteln, also den Glühlampen, Leuchtstoffröhren und Energiesparlampen, bricht schneller weg als gedacht. […] Stattdessen werden LED-Lampen gekauft, also Lampen mit Leuchtdioden. Sie sind energiesparender und in den vergangenen Monaten deutlich preiswerter geworden. Hergestellt werden diese Leuchten aber vor allem in Asien"* (Busse & Giesen, 2014-07-31, p. 2).

manufacturers, many of which are small- and medium-sized enterprises, are forced to act and think globally.

The switch from electric to electronic lighting also puts an end to traditional business models. The traditional European lighting industry was divided into lamp manufacturers and luminaire manufacturers. They are now faced with a sink-or-swim challenge: Luminaire manufacturers have to adapt their low-tech production processes in response to more complicated high-tech procedures. Electronic LED luminaires involve more than metal bending. Their interior needs to be protected against water, heat and dust and they also call for more sophisticated optical systems that reduce glare of the point-like light source. For lamp manufacturers the situation is even more serious, as the long-lasting LEDs render the replacement business with light bulbs and tubes obsolete.

The light source is no longer the weakest part in a luminaire, thus destroying the highly standardised market dominated by traditional lamp maunfacturers like Osram. In a conference, an LED marketing expert spelled out how the old lamp business differs from selling LED lighting: In the past, manufacturers produced, stocked and sold standard fluorescent light tubes and incandescent light bulbs with standardised E27 sockets dating back to and named after Edison (NSR, 2012-09). Today, high power LEDs are improving so fast that new products are developed, presented, sold and are already outdated in six month intervals. As her colleague pointed out, the relationship between LED technology and the traditional lighting business compares to 'a Ferrari in a traffic jam' (NSR, 2012-09; cf. Schulte-Römer, 2013f). The light output of LED light sources is improving rapidly, which means that optics and components need to be constantly adjusted. With projected lifetimes of up to 100,000 hours, LEDs are also expected to outlive other product components, including the luminaire. In this situation, the separation of lamp and luminaire production becomes questionable. Why not integrate light source and luminaire and design them as a single entity? The complete integration would allow product designers to take full advantage of the small and flexible light source and find new shapes. After all, LEDs are not bound to standardised lamps and E27 sockets.

The new situation is also reflected in the merger of two previously distinct trade associations. During 2012 L+B, the European associations of lamp manufacturers (ELC) and luminaire producers (CELMA) held a joint European Lighting Industry Forum and announced their joint new association, which adopted the dynamic name 'Lighting Europe' (NSR, 2012-04-

15/16/17/18). However, as we all know, technological facts are not all that matters. Instead, technologies are shaped by political interests (Bijker, 1992) and in path-dependent ways (David, 1985).

What makes the LED case particularly interesting at the moment is that competing technological paths still coexist. These different paths range between two extremes, namely LED retrofits and 'intelligent' lighting systems, which respectively represent a locked-in and a radical version of the LED innovation. The conservative strategy is thereby considered an interim solution, while the system solution has the potential to open new markets.

Retrofit LED lamps are produced as replacements for fluorescent tubes and most importantly the phased-out incandescent light bulbs and poisonous uncomfortable compact fluorescent lamps in existing luminaires. Since LEDs have different light characteristics, retrofits are technologically challenging and not the optimal solution from a light technological point of view, especially if they are used in old luminaire cases, as an interview partner explained: 'The luminaire is not made for LED, the reflector is not made for LED […] That's already a bad calculation' (Lighting consultant, 2012-01-11, my translation).[145] Nevertheless, LED retrofits are considered a door-opener for LED technology and a way to establish it in the mainstream market for general lighting (NSR, 2012-09).

Intelligent lighting systems, in contrast, are suited to fully exploiting the new characteristics of the new light source. As already pointed out, the tiny diodes are not only energy-efficient but can also be dimmed within fractions of a second. In contrast to high intensity discharge lamps, which take some time to reach their full light output, LEDs are therefore perfectly suited as adaptive lighting systems, even in combination with presence control sensors. In addition to that, the colours or colour temperature of LEDs can be changed on demand. Adaptive systems that allow users to change light colours are not only used in the context of events or festivities. Changing *white* colour temperatures are currently being tested in schools,

[145] OV: *« Donc on enlève l'élément lampe à décharge et on va mettre un élément LED. Donc ça c'est très compliqué techniquement mais en fait le luminaire est fait de telle sorte qu'il n'est pas fait pour la LED, le réflecteur il n'est pas fait pour la LED, il y a tout un système donc en fait quasiment il faudrait ouvrir le luminaire, tout enlever dedans et mettre autre chose. […] c'est un mauvais calcul mais il y a plein de gens qui sont persuadés qu'ils peuvent déjà avoir des petites parts du marché avec ça. Et on le sait parce qu'en fait pour tenter la LED il y en a qui passent par-là »* (Lighting consultant, 2012-01-11).

workplaces, hospitals or old age nursing homes, where they are supposed to enhance the concentration of students and workers or the well-being of patients.[146]

In public lighting, the difference between retrofit and system solutions is less clear-cut. Public lights are already remote controlled and switched on and off by a signal. Retrofits in the sense that conventional light sources are replaced by LED sources in an existing luminaire are less common. After all, LED lighting also means that an LED driver, thermal management and a new optical system or reflector need to be fitted into the luminaire, which then has to be protected against wind and weather. What is often the case though is that new LED luminaire heads are installed on existing poles and that the light control system and energy supply lines remain unchanged. In contrast, the installation of intelligent lighting systems involves new digital control and sensor systems, some of which are still very innovative and unproven for public lighting. While the 'intelligent' LED systems are better suited for exploiting the advantages of the new technology, they are also more demanding in terms of system integration and usage. They challenge technology users, as they involve higher investments, demand new skills and call for a redefinition of personal and public needs for artificial lighting. 'We do not trust LED technology', said a Lyon maintenance manager in 2012. This mistrust is caused by a number of uncertainties concerning the LED products and their producers and is widely shared among technology users in public lighting (NSR, 2013-10-30,31, 11-01,02) as we will see in the following section.

4.2.2 The user perspective: Technological and personal challenges

As we have seen, energy efficiency is a key argument for LED lighting. Yet in addition to its efficacy, LED lighting has a number of attributes that can have positive effects on the light quality and operation of public lighting, as industry and innovation policymakers never forget to point out (cf. European Commission, 2011-12-15b; European Commission, 2013-06; Yamada & Chwastyk, 2013, pp. 53-55). Some of the advantages of LED lighting are rather obvious and can be summarised in a few sentences.

First, the small size of LED packages not only enables new luminaire designs; it also means that one luminaire always consists of many LEDs. If one fails, the street will still be

[146] These applications build on recent findings from medical and psychological research which shows that cool-white colour temperatures with a high share of blue light activates the human brain and supresses the sleep hormone melatonin. Furthermore, psychologists show that daylight therapy can alleviate the symptoms of people suffering from depression (Kunz, 2009)

illuminated. Second, LEDs have an advantage over conventional street lights in regions with cold winters. Unlike gas discharge or fluorescent lamps, which give less light when it is extremely cold, LEDs perform even better at low operating temperatures, in fact, they may be harmed if outside temperatures are too high (Yamada & Chwastyk, 2013, p. 54). Third, LEDs have an advantage over fluorescent or compact fluorescent lamps that contain mercury and are therefore poisonous. On the other hand, the potential negative effects of LED lighting on our health[147] or the exploitation of resources like rare earths elements and the recycling of LEDs and its electronic components are still being discussed (Buchert, Manhart, Bleher, & Pingel, 2012; Kümmerer, 2013, pp. 103-104).[148] These open questions are but one point in a list of uncertainties and issues raised in the context of the innovation. Some of them are directly related to proclaimed advantages, such as longer lifetime, controllability and light quality. Chances are high that these uncertainties will fade away in the near future, as LED technology is further improved and real-life testing proves the innovators' promises to be right or wrong. Yet at the point in time when the first LEDs were installed in Lyon and Berlin, these unresolved issues still played a role.

The *long lifetime* of LED is often highlighted as an argument for LED lighting as it reduces the total cost of ownership despite high initial investments. Innovators argue that LEDs allow public lighting services to prolong their maintenance intervals and hence reduce municipal spending considerably. However, from the user perspective, this advantage and the promised cost savings are not as straightforward as it might appear. In Berlin, several lighting professionals argued that they would still have to clean and check the luminaires. There is also a directive that obliges them to control their electric equipment every four years for safety reasons (NSR, 2012-11-27).[149] Private light operators therefore could not see any financial advantages. One explained that 'LEDs have to be replaced completely, not only the lamp but the complete luminaire including the driver,' which makes LEDs more expensive than conventional light sources (NSR & Toschka, 2013-05-29). Another summed it up as follows:

[147] For instance, there are concerns that the particular light spectrum of LEDs might be harmful for the human eye. The keyword is 'blue hazard' (NSR, 2013-10-30,31, 11-01,02). In public lighting, this issue is less relevant.
[148] Both reports can be found online, see http://www.oeko.de/oekodoc/1375/2012-010-en.pdf, and http://www.bfn.de/fileadmin/MDB/documents/service/Skript_336.pdf
[149] The so-called BGV A3 is issued by the German professional association in order to avoid work accidents. However, the legal status of the regulation is debatable and the document does not prescribe any fixed time intervals for electronic checks (Other lighting professionals referred to three-year intervals). In § 5.2 of the directive it is laid out that checks should take place in certain time intervals. The schedules are to be set so that anticipated defects can be detected in time.' For more information see: http://www.bgva3.de/.

> 'A basic idea of LED lighting is that you need to check on installations only after 12 years. But you then have to check on the luminaire every four years anyway […in order to clean it and check the electric parts.] And now the question is whether I would not rather plug in a fluorescent lamp for €3 or a sodium for €5. In my opinion, LEDs are not worth it…' (Head light manager, my translation).[150]

One of his colleagues rejects the innovation arguing that an LED luminaire would annually cost him 50 Euros more than an equivalent high-pressure sodium luminaire. He also suspected that the cleaning and repair of LED modules and their electronic parts would not be less but more demanding (NSR, 2012-11-27).[151] Manufacturers have already reacted to such fears and are designing LED luminaires so that they can be opened and modules exchanged quickly and easily (product designer, 2013-08-22).

In Lyon, the municipal lighting engineers were also sceptical but are actively testing the new technology, as we will see in more detail below. When the Lyon lighting engineers installed LED lighting they also changed their standard maintenance scheme. As the head of the Lyon maintenance department explained, they routinely replace all 'classic lamps' after three years in a continuous step-by-step process throughout the year while the lamps are still functioning perfectly well.[152] For LED lighting, this interval had to be readjusted on the basis of estimates (2012-01-18). The Lyon municipal engineers are now testing a six-year interval for LED luminaires, which can be considered as a cautious approach given the famous promise of 12 years and more.[153] On the other hand, nobody has ever tested the promised 50,000 operating hours and more in reality on the street. The technology is just too new for real-life experience.

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[150] OV: *„Die Grundidee der LED: Installation, das erste Mal nach 12 Jahren wieder ran. aber man muss ja trotzdem alle 4 Jahre ran - säubern, E-prüfung. Anfahrtskosten und Hochfahrkosten hat man. und jetzt ist die Frage, ob ich eine Leuchtstofflampe für 3 € oder NAV für 5 € reinschraube. Meiner Meinung nach lohnt sich LED nicht, weil man trotzdem hin muss. In Expertenkreisen gibt es dazu unterschiedliche Meinungen. BGV A3 Prüfung muss man nicht machen sagen die einen, andere sagen man muss es machen"* (head light manager; 2013-06-10).

[151] In contrast to conventional luminaires, LEDs need to be well protected against dust or water. They therefore fall into a higher so-called protection class for electrical equipment (NSR, 2012-01-12).

[152] These intervals are calculated on the basis of the already proven average operation time of the conventional sources. That means that standard replacements are scheduled for the moment when the risk of technology failure becomes so high that extraordinary repair and interventions outweigh the cost of replacing the lamps altogether.

[153] OV: *« En Asie : Les produits n'ont pas le même prix, ils sont beaucoup moins chers. Et ce n'est pas la même qualité. Donc ils peuvent annoncer des durées de vie très longues, si ça ne marche pas, ils remplacent, c'est tout. Et en Europe on ne peut pas faire ça, donc on a toujours des produits... et il y a toujours des gens pour croire que c'est comme ça que ça marche. 50,000 heures, on met de la LED partout, sauf que pour en revenir à ce qu'on disait tout à l'heure les villes ne sont pas dupes (= ne croient pas tout ce qu'on leur dit), en Europe »* (Lighting consultant, 2012-01-11).

The manufacturers' promises about average LED lifetimes are based on laboratory simulations, the above-mentioned stress tests. In addition, most luminaire manufacturers do not produce LEDs and electronic components themselves and thus also have to rely on the information and promises of their suppliers. A French policy-maker explained that only 10,000 hours were officially guaranteed, for good reasons:

> '…I think good LED products last longer than 10,000 hours. But do you know the lifetime of LED products? There is no way to test or learn during 50,000 hours before selling it. So you are doing simulations and these simulations must be reviewed' (Sustainability consultant, 2011-12-15/16).

Manufacturers have so far been careful and have not provided too much written information on product lifetimes in their catalogues and only started to offer their clients long-term guarantees on LED products in 2010 (lighting consultant, 2012-01-11).[154] In addition, and as already mentioned above, even the indestructible light source LED is only useful if the other components in the luminaire, especially the LED drivers, do not fail earlier.

A second advantage that is regularly highlighted is the above-mentioned possibility to control the light flux and light distribution of LED lighting. This light control in time and space allows municipalities to further reduce their energy consumption, provided they only light where and when needed. In contrast to conventional gas discharge or fluorescent light sources, which take some time to reach their full light output and degrade faster the more they are switched on and off, LEDs can be dimmed steplessly and switched on immediately. Furthermore, LED light does not spill in all directions and the light distribution by LED luminaires can be customised so that only streets are lit but not the house facades or gardens in the neighbourhood. This not only has the positive effect of avoiding needless energy consumption, but can also reduce light nuisance, a topic that has gained more public attention (Held, Hölker, & Jessel, 2013).[155]

Despite these great potential advantages, most municipalities see themselves as having more pressing problems than purchasing new and often unproven digital control systems for public

[154] During L+B 2010, an Italian manufacturer received attention for offering its clients five-year guarantees on LED street lighting luminaires. Since then, more firms have followed and guarantees on luminaires, including LED drivers, have become more common (lighting consultant, 2012-01-11; NSR, 2010-04-12/13/14/15/16).

[155] The issue is addressed by the so-called dark sky movement and some EU governments, including France, have passed legislation to reduce light pollution (Meier et al., 2015). However, the topic is still problematic from a regulatory point of view since it is difficult to measure light pollution and to regulate both private and public light sources (Krause, 2015; NSR, 2012-05-08).

lighting (Sustainability consultant (EU), 2012-28-11; NSR, 2012-09). System changes involve large investments, since they concern not only a few but all light points in a city. Furthermore, 'intelligent' electronic control systems are less recommendable if existing infrastructures are old or outdated. In such cases, it might be more effective and economic to control the public lights with established, less sophisticated control technology (telemanagement expert, 2012-01-26). Last but not least, digital control systems only make sense if they are used by competent system operators, which is not always the case as we will see below (6.2.1.).

A third advantage of LED technology in public lighting is its supposedly good light quality. LED chips can be produced in different white colour temperatures—from warm to cool white (mostly between 3,000 and 6,000 Kelvin). Cool-white colour temperatures are more energy-efficient, but warm-white lighting is more socially accepted, at least in Northern Europe.[156]

Furthermore, high-quality LEDs also have good colour rendering (with CRIs around 90), which means that we perceive colours more or less as we would see them in daylight. Lighting professionals therefore prefer LED lighting to conventional light sources—like high-pressure sodium lamps—that are equally efficient but emit yellow light.[157]

The possibility of switching from yellow to white lighting corresponds with municipal objectives: Better colour rendition is associated with more safety and more visual comfort in public spaces. In Los Angeles for instance, the police welcomed the white LED lighting, arguing that it made their job easier (NSR, 2011-12-08a; OL & JQ, 2012-02-07). Photometric experiments support that impression. They showed that white light is *perceived* as brighter than yellow light with bad colour rendition as it improves facial recognition and enhances human night-time vision (TUB lighting engineer, 2013-02-06). These scientific findings also suggest that the light levels in public spaces can be reduced where white lighting is used.[158] Last but not least, lighting designers highlight the issues of sociability and well-being, arguing that public spaces should be lit for people, that is, with good colour rendering, and not only brightly and efficiently in yellow for car traffic (NSR, 2011-09-30, 2011-12-09b).

[156] Light manufacturers report that cool-white light does not sell in Northern Europe (NSR, 2011-10-19/20/21/22). This is also in line with social-scientific findings about the social meaning of lighting (Bille & Sørensen, 2007).
[157] HPS lamps 'have colour temperatures of approximately 2,000 K, providing a yellow/orange light, and color rendering indices as low as 21' (cf. DOE, 2010-04; Yamada & Chwastyk, 2013, p. 55).
[158] This new state of the art will also be considered in the update of the European standard for road lighting, the EN 13201 (see 4.3.2). It is currently under revision (NSR, 2011-12-09 #2175; standardisation professional, 2010-12-02).

Yet the light quality of LED products has also caused great problems. The first real-life installations revealed some serious problems like flickering lights or the rapid degradation of the colour or light flux of the LEDs.[159] An EU-wide public consultation, in which the European Commission invited all stakeholders to give their feedback on the innovation, showed that uncertainties concerning the quality of LED products are a major market barrier (European Commission, 2012-07-06). Indeed, some of the consumers' trust was lost in the disruptive innovation process when bad products were pushed on the market too early and users lacked the information they needed to make conscious choices.[160]

Solid-state lighting is so different from existing lighting technology that existing evaluation techniques and quality indicators needed to be adapted and relearned (cf. CELMA, 2011). This makes it very difficult for potential users to compare LED products to equivalent conventional light sources. For instance, some key photometric parameters did not properly apply to LED light and had to be amended or revised.[161] Even more importantly, the taken-for-granted relationship between light output and energy consumption is lost. Who knows what a 60W LED looks like? How could anybody know since the energy consumption of LED luminaires also depends on the light temperature of LED modules and their other electronic components? In order to offer users the information they need and to gain back their trust, the lighting industry and policy makers have developed new parameters and quality certificates like the U.S. Eco Star or the EU Energy Label, which should help users compare products. These labels also have the pleasant side-effect of keeping cheap competitors out of the

[159] For instance, the colour of LEDs can change if the phosphorus coating over the chip, which converts the blue light into white, degrades. The cause can be voltage fluctuations or too hot exterior temperatures.

[160] In the face of the disruptive innovation, municipal lighting experts are not only confronted with an unfamiliar technology but also with new business partners or, even worse, old business partners who have lost track of the technological development. Both manufacturers and clients deplore a lack of transparency and that trust has been lost (NSR, 2013-10-30,31, 11-01,02). Incumbent lighting firms blame new market entrance for destroying the market with their inferior products with a bad light quality. Clients complain that their suppliers provided them with incomplete or even false information, maybe not even on purpose but because they did not know any better themselves. Faulty technology and false promises call for more and independent testing as well as for a better education of sales personnel and clients.

[161] For example, the colour temperature of LED light cannot be precisely determined with established methods and measures (in Kelvin), because electroluminescence has different characteristics than a black-body light source (Licht.de, 2010). The additional reference for describing the colour temperature of LEDs is the so-called MacAdams ellipses. See: http://www.zumtobel.com/led/de/23643_22960.html, last access 2014-08-10.

European market.[162] Products are also tested and evaluated by independent testing institutions or in the lighting engineering departments of universities.[163]

Furthermore, standardisation is crucial not only for technology producers[164] but also for users (cf. Blind, 2004, 2008) in two respects. First, in the face of the rapid technological development and market disruptions, municipal users of LED technology worry about so-called lock-in situations (cf. Arthur, 1989). Street lighting equipment is expected to last for 25 years. LED technology is outdated after 6 months. Product lines are discarded and every LED module comes with unique components that might also no longer exist in the future. 'How are we going to maintain these materials?' asked an installer (2012-01-27). Yet technology users worry not only about the future availability of spare parts but also wonder whether their suppliers will survive the disruptive innovation (NSR, 2011-12-02a).

In addition to this, the idea to purchase an expensive luminaire with *inbuilt* LEDs that cannot be replaced can be disturbing—especially as the lifetime of LEDs has not yet been tested under real-life conditions. Manufacturers have already reacted to this worry and begun to produce standardised LED modules or 'LED engines' that include LED modules, electronic drivers and optical systems and can be replaced as one. The LED engine in a 2011 luminaire design can thus be replaced with a 2014 product that has the same form, light distribution and light output but uses more powerful LEDs and consumes less energy. The standardisation of LED components thus reduces uncertainties concerning the future availability of compatible LED products and enhances transparency in the market.

But the innovation does not only cause problems between users and producers but also renders the relationships between technology users problematic. In other words, not only the 'making-of' LED technology is problematic, but also the 'making-with' (Rammert, 2008, p. 2). New skills and competences are not only required on the innovators' side but also among those who light our cities on a daily basis. The EU consultation report addresses the issue of 'education, vocational and lifelong learning' as follows:

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[162] On the other hand, certification processes also present a problem as they are time consuming and can take longer than the development of a new LED product line (NSR, 2013-10-30,31, 11-01,02).

[163] In the U.S. the DOE *CALiPER* programme (Commercially Available *LED* Product Evaluation and Reporting) was launched in 2006 to conduct independent product testing on LED products on the US market (DOE et al., 2010-04).

[164] Standards are also needed in business-to-business relationships, in order to guarantee the compatibility of products across production chains. In 2010, lighting manufacturers founded the international consortium Zhaga, which is named after the place in China where they first met. Zhaga standards define product interfaces and thus ensure the interchangeability and compatibility of LED components from different manufacturers.

> 'Respondents acknowledge that current vocational and lifelong learning and training schemes are not sufficient to meet the demand of the future SSL markets. There is a shortage of highly qualified work force and industry representatives are especially keen to indicate that this problem will increase in the future. Potential measures should focus on attracting more people into the related professions and to increase the pan-European vocational training' (European Commission, 2012-07-06, p. 4).

Similarly, the head of the Lyon public lighting maintenance team explained that they are 'obviously thinking about the profile of the people we'll be hiring in the future. Will they continue to be electricians or will we hire more electronics engineers instead?' (2012-01-18).

Another interview partner suggested that the shift from electric to electronic lighting might render many of the blue-collar jobs in the field of maintenance obsolete (Lyon lighting designer, 2012-01-09). Some installers told me that LEDs would cost them their jobs.[165] The idea is not entirely unfounded. The LED business might indeed have disruptive effects on the installation and maintenance sector for the above-outlined reasons—which might also partly explain why some light operators are reluctant to install LEDs. 'The job is in the middle of a complete change,' explained a French installer (2012-01-27).[166]

We can thus conclude that the introduction of LED lighting not only challenges the lighting industry but also its potential users. Professionals in the domain see themselves confronted with temporary uncertainties concerning the maturity, quality and compatibility of the new technology or the reliability of their industrial partners. They are also personally affected, as the innovation requires them to develop their skills and gain new knowledge in fields like electronics and light programming. This is particularly the case when LED technology is installed and used 'intelligently' and not 'only' as a retrofit solution.

Considering the challenge and the uncertainties associated with LED lighting from the user perspective, it appears less surprising that potential municipal LED users have so far been hesitant to install the innovation on their streets. In 2011, the authors of a McKinsey study observed:

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[165] According to a French installer, the new challenge is to know the correct power supply—'the output of LEDs is not the same if you supply them with 150 mA, 500 mA ou 700 mA' and it also has an effect on the product lifetime (2012-01-27). Since his company does not want to rely on the information and education offered by manufacturers, they have established their own programme to train their workers.

[166] OV *« Le métier est en train de complètement changer »* (lighting installer 2012-01-27).

> 'The advantages of new LED lighting technology are well tested and beyond doubt. Nevertheless, LED lamps have achieved little market penetration and are predicted to make far slower progress than comparable disruptive technologies' (Baumgartner, Wunderlich, & Wee, 2011, p. 66).

In this situation, state-funded programmes incentivised cities and communes to act as forerunners, as we will see in the following section.

4.2.3 The policy perspective: Public LED lighting as lead market

LED lighting first entered urban spaces through several niche markets, as mentioned above. 'From traffic lights to road signs, from automobile taillights to outdoor displays, from landscape to accent lights, solid-state light sources that are harbingers of the next lighting revolution have already arrived,' wrote the authors of an 'introduction to solid-state lighting' published in 2002 (Zukauskas et al., p. xi). It was only after 2005 that LED technology was powerful and mature enough for outdoor lighting. The first products were developed, presented and tested in the subsequent years (lighting consultant, 2012-01-11, NSR, 2012-09). The first LED luminaires in street lighting date from 2007 or 2008. Many of these early fixtures were installed in residential streets, where light levels can be lower, or in 'streets with less traffic, or for pedestrians and bikes only' (Valentová et al., 2012, p. 11). But luminaires were installed in such small numbers that it would be misleading to speak of the LED in public lighting as being a reality in 2007.

Three years later, the situation had changed. In 2010, LEDs attracted considerable attention during the world's leading world fair for lighting, Light+Building (L+B). Almost all the exhibitors had LED products on display (NSR, 2010-04-12/13/14/15/16). Attendees jokingly dubbed the event 'LED+Building'. 'The 2010 L+B showed that LED technology is now mature,' concluded a German innovation policy maker from the German Federal Ministry for Education and Research (BMBF, see NSR, 2010-07).[167]

[167] After the 2014 L+B, a lighting designer reported that LED products had displaced conventional light sources. Manufacturers had presented *only* LED luminaires (personal conversation).

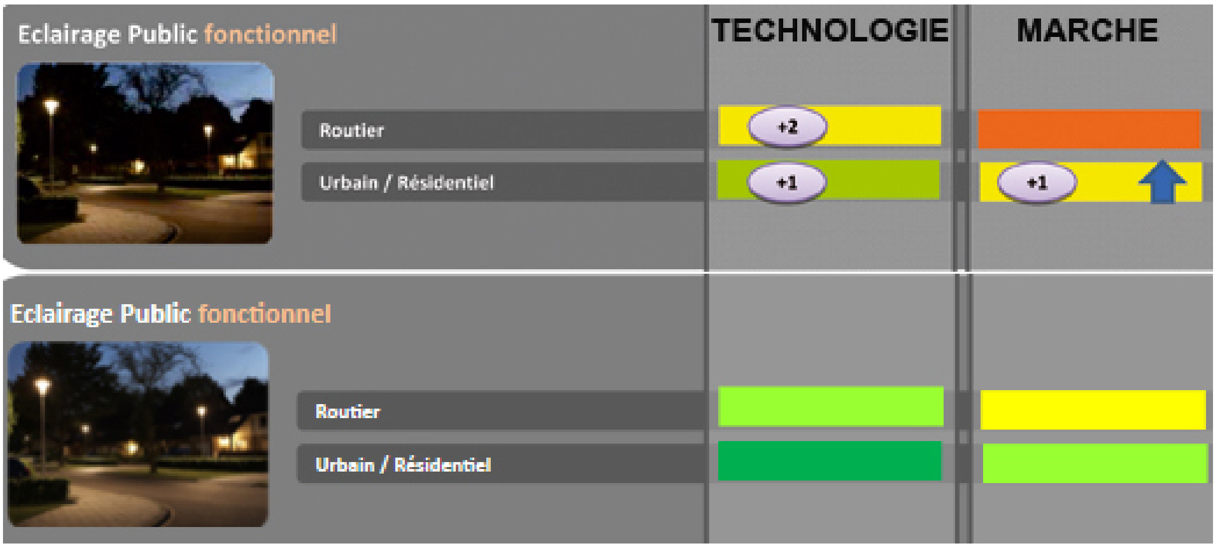

Figure 4-3: 'Maturity grid' for exterior LED street lighting products, Dec. 2010 & Oct. 2011.[168]

Later in the same year, during the ForumLED in Lyon, the federation of the French lighting industry (Syndicat de l'éclairage, 2010-11) presented a survey which indicated that LED products for *urban residential areas* were out on the market and in the manufacturers' catalogues and 'at least equivalent to classic solutions' in terms of their performance (Figure 4-3, upper section, 'technology' column, second line in light green). It also indicated that reference projects and real-life evaluations of public LED lighting already existed (column 'market', yellow). The overview also showed market dynamics (blue arrow) and indicated the fast evolution of LED technology ('+1'). Similarly, LED lighting for larger roads developed rapidly ('+2') but was still in an earlier phase (first line), with prototypes (yellow) and first pilot projects (orange).

One year later (Figure 4-3, lower column), an updated overview showed that LED products had moved up the maturity scale. LED products for both road lighting and urban residential streets now showed a 'significant market penetration' in France (light green). Residential urban LED lighting was even categorised as 'mature' (dark green) in technological terms (Flet Reitz, 2011, p. 38).

Nevertheless, the uptake of the innovation remained generally slow (Baumgartner et al., 2011) and there seemed no pressing demand for an expensive new light source (municipal consultant, 2012-02-03).[169] In this situation, the governments set up demand-side innovation

[168] Source: Syndicat de l'Éclairage, http://www.afe-eclairage.fr/docs/10320-ext.pdf, last access 2015.11-22.
[169] The participants of the above-mentioned WZB Workshop (see 3.1) suggested that there is comparatively little need for investment and replacement of light points as urban spaces are already brightly lit. It was suggested that

programmes with the twofold objective of creating lead markets for an energy efficient technology and helping their national lighting industries to survive the disruptive innovation process.[170] The role of cities and communes as innovative public procurers was thereby underlined (European Commission, 2011-12-15b).

Public lighting is considered an important market for LED outdoor lighting across the world, because 'growth in this niche is driving the technology improvements and lowering prices' (The Climate Group, 2012-06, p. 9). In the USA, the Department of Energy (DOE) has created a Municipal Solid-State Street-Lighting Consortium that promotes the use of LED lighting throughout the country, for instance, in a regular online webinar that offers lighting professionals and policy-makers a chance to form an opinion and learn more about the technology or from their colleagues' experience with the innovation (NSR, 2013-05-08). In the USA, 'the number of LED streetlight installations has been steadily climbing since 2010' (Yamada & Chwastyk, 2013, p. 40). Between 2010 and 2012 it increased from about 0.5 per cent (about 200,000 luminaires) to 'a little over two per cent' of all installed street lights in the USA (Yamada & Chwastyk, 2013, p. 40). As a forerunner, the City of Los Angeles set up a replacement programme in 2009 and has since then converted more than 115,000 light points to LED.[171]

In Asia, China was a forerunner in terms of LED deployment. With the so-called '10,000 lights in 10 cities' programme, the Chinese government created a lead market for its important SSL industry as early as 2009 with the aim of installing one million LED lights in streets, tunnels and infrastructural facilities (Gu, 2009-07-22; Lin, 2011-07-01).

In Europe, the deployment of LED luminaires has also gathered speed thanks to governmental funding and innovation programmes. As already mentioned, the European Commission supports research and development in photonics and the deployment of LED lighting under the umbrella of its Digital Agenda. After a Green Paper had been published (2011-12-15b), the European Commission sought feedback from stakeholders through a public consultation

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Europe would never be a big market for LEDs. Yet although cities are usually not inclined to invest in new lighting infrastructures (see 4.3), they also do not want to lose touch. Thus, they test the innovation in pilot projects—'as an experiment it is a fantastic thing', said one participant (Schulte-Römer, 2010, p. 30).

[170] A German policy maker explained that they had launched the national SSL lead market initiative as they had 'found that there was a market failure' (NSR, 2010-07, my translation), which justifies interventionist demand-side innovation policies as outlined in the appended chapter 10.2.

[171] An employee of the City of Los Angeles, that began testing LED lighting at a very early stage, told me that some of the early luminaires were very efficient but gave *green light*—inacceptable from a residential and hence, municipal point of view (OL & JQ, 2012-02-07).

process (European Commission, 2012-07-06). An expert 'EU Task Force on Solid State Lighting for Cities' was assembled to discuss the opportunities presented by public LED lighting and the barriers to its implementation. The final report lists a number of demonstration projects, outlines contracting models for financing refurbishments and encourages municipalities to 'move to SSL now' (European Commission, 2013-06). In addition to these initiatives, the EU has funded and still finances transnational expert exchanges on SSL experiences, demonstration projects, living labs and recently also a pre-commercial procurement programme.[172] In this project a group of cities from different EU countries is currently creating product specifications for the LED luminaires and systems they would like to procure in the future.

In Germany, the Federal Ministry for Education and Research (BMBF) launched an SSL 'lead market initiative' which involved the competitive funding scheme 'communes in new light' *(Kommunen in neuem Licht)*.[173] The programme encouraged municipalities to develop and propose LED projects. The ten winning projects received funding, but even more projects were completed. The installations were also scientifically evaluated and widely publicised in the media and conferences. During the 2012 L+B, the German BMBF invited early municipal users of LED lighting to share their experiences with public LED lighting in a conference with the title 'Citylight – LEDs for modern, efficient early lighting'. It was claimed that Germany has indeed become a lead market for LED products thanks to municipal and federally funded LED projects (BMBF, 2012-04-16; NSR, 2012-04-16).

These demand-side policies are the most obvious incentives to install LED lighting, but they are not the only ones. As we will see in the following section, the diffusion of LED products is also supported by environmental funding schemes (4.3.1). In addition to that, the innovation process is also accompanied by standardisation and non-technological light-related developments that create windows of opportunity for LED installations.

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[172] For the pre-commercial procurement project see: http://www.luciassociation.org/sslerate-project-eu-page.html, for the living lab see: http://www.lightinglab.dk/uk/services/living-lab/, last access 2014-08-20. Other programmes include Esoli, Greenlight, etc.
[173] http://www.bundesregierung.de/Webs/Breg/DE/Themen/Forschung/Schluesseltechnologien/Photonik/led/led-stadtbeleuchtung.html, last access 2014-08-13.

4.3 Windows of opportunity for LED lighting

Innovation is not the most obvious task of public lighting services which supports the market-failure diagnosis. Although infrastructures need to be renewed from time to time, they are primarily obdurate (Hommels, 2005a). Lamp poles are considered to last for 50 years, luminaires for 25 to 30 years (Van Tichelen et al., 2007-01, p. 25). The estimated lifetimes of products and infrastructures are taken as a basis for the calculation of investment needs. As a result, communes and cities should refurbish around 3.5 per cent of their luminaire park and 2 per cent of their light poles per year (NSR, 2013-05-29; telemanagement expert, 2012-01-26). In reality, lighting equipment is used even longer. The average German luminaire is 21 years old (PWC & WIBERA, 2010). As long as urban public spaces are lit and the technical equipment is functioning, public investments in lighting infrastructures are usually not very high up on the political agenda. They are run by experts and replaced in a routine way if municipal budgets allow it. The investment backlog and outdated infrastructures tend to be low-interest topics unless the lights go out or pose a safety risk.[174] In most places, the lack of public interest and the notoriously empty public purses speak against the introduction of LED lighting. But even if public lights are modernised, one might achieve more energy savings per Euro by replacing old luminaires with cheap high-intensity discharge technology instead of installing very few expensive LED luminaires (NSR & Toschka, 2013-05-29).

However, there are LED-related scientific, political and societal developments that affect the public perception of 'the new'. In the following, I will outline the relationship between EU climate change policies and LED deployment in more detail and also outline how technical standards for road lighting, urban regeneration or the media create a 'favourable' situation for LED lighting despite all investment backlogs and urban obduracies.

4.3.1 A favourable climate for LED lighting: EU Ecodesign and CO_2

Outdated and ineffective infrastructures alone do not automatically lead to action, nor do they create a demand for LED lighting in particular. In this situation, EU and national governments set important incentives, as already mentioned. The enormous energy-saving potentials associated with LED perfectly match with EU climate change policies. The new technology

[174] In some places, municipal engineers and city planners worry that concrete lamp poles will collapse if their government does not grant them the money to refurbish them. They threaten to dismantle the light before they become a public safety risk (personal conversation NSR, 2013-09-18/19/20/21).

thus allows policy makers to align two popular political objectives, namely innovation and the protection of the global climate. Accordingly, the 'EU Task force on SSL for Cities' reports that the 'current EU policy context is particularly favourable for the deployment of high quality LED lighting in outdoor and indoor installations' (European Commission, 2013-06, p. 11).

In the field of lighting, the EU Ecodesign Directive, a policy instrument for stimulating the demand for more efficient energy-related products (ErP also Directive 2009/125/EC), is particularly consequential (NSR, 2012-09).[175] It requires that municipalities purchase products and services 'with high ratings for energy performance' (European Commission, 2013-06, p. 11) by setting energy-efficiency targets for specific product groups. The worst performing products are phased-out.

The Ecodesign Directive has become famous for banning the beloved light bulb from supermarket shelves and living rooms. But it also affects public street lighting. Like the incandescant light bulb, high-pressure mercury lamps (HPM) will be phased out by 2015. The need for modernisation was and still is enormous. For instance, HPM luminaires constituted 33 per cent of the installed base of street lighting in France in 2006. In Germany (2003) luminaires equipped with HPM lamps amounted to 45 per cent (Study for the European Commission 2007-01, p. 76). A 2007 EU report shows that French and German communes were quite similarly affected by the ErP directive with 8,570,000 remaining HPM luminaires in France and 9,120,000 in Germany (Van Tichelen et al., 2007-01, p. 76).

The ban is already affecting municipal modernisation strategies and opens a window of opportunity for LED lighting. This is not only due to the fact that the directive sets new sustainability standards but also because it is accompanied by EU and national investment programmes that incentivise and help cities and communes to refurbish their lighting equipment in time. A number of environmental agencies acted as consultants helping cities and communes to apply for European funding. In Germany, the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) set up an annual funding scheme as part of its National Climate Initiative in 2008. The programme helps municipalities

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[175] In 2009, the ErP 2009/125/EC replaced the EuP. This switch from energy *using* products (EuP 2005/32/EC) to all energy *related* products (ErPs) extended the scope of the directive. With regard to LED lighting, the Regulation 1194/2012 of December 2012 outlines the implementation details. It 'completes and complements the Regulations 244/2009/EC and 245/2009/EC' (European Commission, 2013-06, p. 11). The EU regulatory framework is implemented by the EU member states on the national scale respectively.

to modernise their public lighting infrastructure. The full funding was only granted if at least 60 per cent of energy could be saved. Lighting manufacturers actively informed their municipal clients about these funding opportunities and helped them plan their new lighting. Conversations with German municipal engineers showed that they perceived the programme as a LED funding scheme. (NSR, 2012-03-27/28/29; Wagner & Schulte-Römer, unpublished document). Today, the BMU website features numerous successful cases of LED installations in German communes and cities.[176]

In France, the French Agency for Environment and Energy Management (ADEME) provided similar support including funding and educational programmes. Yet during my research period, the French policy executives seemed more reserved to LED lighting than their German colleagues. In Decembre 2012, an ADEME expert explained that they 'don't recommend using LEDs in public lighting especially because we observe that LEDs are not as efficient as other kinds of sources' (sustainability consultant, 2011-12-15/16). Making reference to earlier market incentives for flourescent lighting, he also pointed to the dangers of promoting immature technologies too early and in the absence of quality standards:

> 'On the market, you have good products and you have bad products and you have no way, as a consumer, or a mayor, to differentiate between them because there is no European Energy Label on any products. The norms are not fully adapted for LEDs and that is why we need to push the norms and to work strongly on this because for LED products, we are making the same mistake as for fluorescent lamps at the beginning. […] In the beginning, 10 or 15 years ago, there were products on the market, quite expensive, more expensive than now, and they were lasting 1000 hours and they were bluish, the white was bluish. The people bought the products and were very disappointed because it only lasted 1,000 hours instead of 10,000 or 15,000 hours and the light was bluish. After that we had to tell the people, ok, at the beginning they were rubbish but now there are norms, regulations, etc. and the products on the market are checked, good quality products and we need them to save energy. But people are now resistant to buying them' (sustainability consultant, 2011-12-15/16).

But there is not only funding. National and EU policy makers also encourage municipalities to explore and use the possibilities of contracting models and public-private partnerships (cf. European Commission, 2013-06). Since the new technology causes high upfront costs but

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[176] See for instance: https://www.klimaschutz.de/de/projekt/sanierung-von-teilen-der-stra-enbeleuchtung-mit-led-technik, last access 2014-08-10.

also has high energy-saving potentials, it can be attractive for private firms to refurbish and operate public lighting infrastructures until they have amortised.

Furthermore, manufacturers offer clients ready-made tools, for instance online masks, to calculate the total cost of ownership (TCO) and amortisation periods for LED equipment. In these calculations, energy efficiency is often featured in a twofold way. First it has a direct impact on cost savings thanks to reduced municipal energy bills. Second, the reduced energy consumption is often expressed in 'saved tons of CO_2' translating the efficiency of LED lighting not only in terms of cost but also into a widely accepted 'green' public justification (cf. Thévenot, 2002).[177] The innovation is thus directly linked to the global problem of climate change and branded as a direct answer to the Kyoto protocol.

We can conclude that climate change mitigation aids the current innovation in lighting. It opens a window of opportunity for LED installations—even if this is no automatism. In fact, some communes have developed counter strategies and switch off their public lights, which is indeed the most energy efficient and also cheapest solution to the climate change problem. For cities however, switching off their public lighting is less of an option. On the one hand, urban life is culturally and politically unthinkable without artificial lighting (see chapter 9). Dark urban spaces are associated with backwardness, states of emergency or decline (Besecke & Hänsch, 2015; Hirdina & Augsburger, 2000). On the other hand, municipalities of cities are legally bound to illuminate their public spaces for safety reasons. In this context, the road lighting standard EN 13201 functions as an important but ambivalent reference.

4.3.2 Adapting standards to LED light: The EN 13201 under revision

The European Norm EN13201 directly concerns municipal light planning and indirectly also the development and design of products. It offers light planners guidance on how to plan lighting installations in line with the current technical state of knowledge in light engineering.

[177] For instance, the 'efficiency calculator' of one German manufacturer accounts for the 'total profit of ownership' and the energy savings in tons of CO_2 (NSR, 2010-11-10).Such online calculators can also be understood as black-boxed 'interessement devices' (Callon, 1986b). The device offers its users clear instructions on how to insert values and also explains how they relate to each other in the efficiency calculations. But although the device leaves users a lot of room for adjusting their entries to actual empirical values there are also values that are automatically provided and processed by the program (manufacturer instructions, 20 pages). The very fact that so much data can be manually entered into the program shows that efficiency calculations are contingent and relative to concrete situations.

For example, the EN 13201 outlines which light levels are appropriate for which type of street.[178]

It also explains how to measure light levels in public spaces according to scientific procedures. The EN 13201 consists of four parts. While parts 2 to 4 apply across Europe,[179] the standardisation experts, who come from different EU member states, could never agree on a joint version of the first part. As a result, this part is still provided by national standardisation agencies like DIN in Germany (DIN EN 13201-1) and AFNOR in France (NF EN 13201-1). This lack of homogenisation reflects and reproduces national ways of lighting cities in Europe because the first part of the EN 13201 contains the information on how quality criteria and levels of brightness should be translated into real-life situations. In particular, it lists the criteria according to which different types of streets should be classified and lit accordingly.[180]

A fifth part on 'energy efficiency requirements' is currently being developed as part of a general revision of the standard.[181] This revision is also a response to the LED revolution which has created new scientific facts, which now need to be integrated into the technical recommendation. As we have seen, LED light differs from conventional light sources in terms of its spectral distribution and colour rendering and therefore challenges existing photometric models. As a result, scientific measurements and quality criteria in light engineering, which also form the basis of the EN 13201, had to be adapted. Furthermore, LED allows for new lighting solutions like adaptive lighting and has a different light distribution than conventional light sources on our streets. Accordingly, real-life measurement procedures as they are outlined in the European standard also required an update.

Thus the current revision of the European standard serves the integration of LED-related knowledge and possibilities, for instance by developing guidelines on how to dim in line with the technical recommendations, safety and quality criteria of lighting engineers. In other

[178] Streets differ with regard to their traffic, their width, surface, built environment and structures over and underground. All these factors are taken into account in public lighting.

[179] These parts cover 'performance requirements' (part 2), the 'calculation of performance' (part 3) and 'methods of measuring lighting performance' (part 4)—in other words, quality criteria for good road lighting and how they are calculated and measured correctly. See: www.straßenlicht.de, last access 2013-10-12.

[180] For instance, mainstreets with parking spaces, a green strip or subdivision in the middle and a speed limit of 50km/h require different light levels than residential streets with a speed limit of 30km/h.

[181] The revision was published in 2003/2004. http://www.cen.eu/cen/Sectors/TechnicalCommitteesWorkshops/-CENTechnicalCommittees/Pages/Standards.aspx?param=6150&title=Light%20and%20lighting, last access 2014-02-09.

words, by acknowledging innovative ways of lighting in the EN 13201 the standardisation experts create a space for LED technology in public light planning. Not surprisingly, the lighting industry is actively involved in the standardisation work.

The EN 13201 is developed by experts in light engineering at CEN, the *Comité Européen de Normalisation*.[182] The standardisation process is based on the consensus of experts and described as open to all stakeholders, namely 'industry, trade federations, public authorities, academia, NGOs and other representatives' (ibid). 'A European standard is shaped by those who contribute to its development', it says on the CEN website.[183] In reality, most CEN experts are assigned by the lighting industry and can be considered as standardisation professionals (cf. Jakobs, Procter, & Williams, 1996). The national standardisation bodies or trade associations of the EU member states each nominate three delegates to participate in the joint working groups. Only one of the three German delegates is a freelance lighting engineer.[184] In France, where the AFNOR is linked more closely to the government than the DIN, the only non-industry delegate is an employee of the CERTU,[185] the scientific advisory body of the French Ministry for Sustainable Development and Planning. He was assigned to represent the municipal and government's positions in response to a conflict, namely after municipal stakeholders had refused to accept the CEN propositions on the national level. He describes this 'crisis' as an effect of mal-representation. Before the 'crisis', only three manufacturers had been considered by CEN to represent the French position. The CERTU scientist now plays the role of an advocate of the French municipalities on the European level (NSR, 2011-12-09a). Yet, technology users show little interest in the process. In an interview, the lighting engineer suggested that municipal actors feel they are not competent to participate in the scientific standardisation work. 'They have the experience but not the expertise' (NSR,

[182] On the European level, the technical committee TC169 'light and lighting' collaborates with the TC226 'road equipment' in a joint working group (JWG). More precisely: the working group 12 within the TC 169, which is chaired by the DIN as the secretary and the TC226 chaired by AFNOR http://www.fnl.din.de/cmd;jsessionid=EAF304AFEA37E6BF8940EB6882D8E78F.1?level=tpl-untergremium-home&subcommitteeid=54753977&languageid=en and http://www2.afnor.org/espace_normalisation/structure.aspx?commid=1467&lang=english, last access 2013-09.

[183] The CEN also collaborates with the CIE, the *Commission Internationale de l'Eclairage*, the scientific organisation of light engineering. The CIE facilitates the scientific and professional knowledge exchange on light and lighting. According to a French CEN member, 75 per cent of the AFNOR representatives are also CIE members. It produces technical reports and recommendations on light applications and light engineering in general. The ISO has assigned the CIE to develop international standards on its behalf. The work of the CEN TC169 is also based on CIE publications. In order to avoid incompatibility and confusion, CEN and CIE have also signed a collaboration agreement in 1999 (Stockmar, 2004).

[184] He is also a true 'standardisation professional' (cf. Jakobs et al., 1996). A light planner describes him as 'the pope of standardisation in Germany'.

[185] Centre d'études sur les réseaux, les transports, l'urbanisme et les constructions – *Ministère de l'Écologie, du Développement et de l'Aménagement Durables*.

2011-12-09a).[186] He also explained that from a technology users' point of view the standard is too complicated and needs to be simplified, while it appears oversimplified from a light engineering point of view.

The complexity of the standard affects its application. Abstract and generally applicable as it is, the EN 13201 needs to be translated into concrete requirements and lighting installation. In order to provide good or very good lighting fixtures, light planners have to interpret it (TUB lighting engineer, 2013-02-06).[187] Yet, during my research, I found that the EN 13201 is not only interpreted by municipal actors, but also misinterpreted (NSR, 2012-09-12/13/14). Although the road lighting standard is a non-binding technical *recommendation*, some municipal actors refer to it as a quasi-law (Köhler, 2012).[188] This is somehow paradoxical since a great number of urban lighting installations do not comply with the standard—at least in Germany (sustainability consultant (EU), 2012-28-11)—and many civil engineers are not even familiar with its quality criteria, calculations and measurement procedures (Chain, 2010).

Against this backdrop it seems that, although the EN 13201 is a recommendation on how to install and use lighting technology, it affects LED lighting rather on the producer-side than on the user-side. The standard channels and aligns technology users' demand and allows manufacturers to produce and label their products according to these predictable expectations (cf. Blind, 2004). It also presents an expert framework for evaluating lighting installations and products, including LED novelties.

I conclude that the European standard affects but does not fully account for public lighting practices on the local level. It offers manufacturers and their clients a common ground for evaluating products in line with the current state of scientific knowledge in light engineering

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[186] Similarly, a Berlin light engineer who attends the DIN lighting group meetings on behalf of the Berlin Senate suggests that the standardisation work is too scientific for municipal actors. When asked how he represents the interests of the Berlin Senate Administration in the DIN committee he denied it and explained. 'They do not get anything out of it,' because the DIN working group discussed *basic* scientific questions and did not plan lighting for streets. He further argued that design aspects that might be important for cities were not taken into account in the DIN working group (Berlin lighting engineer, 2012-12-13, my translation).OV: *„Die haben gar nichts davon. Denn die Einflussnahme… Es wird ja im FLN 11 nicht Straßenbeleuchtung geplant. Es werden ja Grundlagen festgelegt'* (ibid).

[187] A lighting designer even argued that the standard needs to be 'hacked', which implies that a planner knows the norm well but knows how to play with it (Schulte-Römer, 2010).

[188] The EN13201 is not legally binding but legally relevant, since courts can draw on it as a reference, for instance if an accident happens in the dark on a public street and a party involved decides to sue the city for not providing the appropriate lighting.

and adjacent fields.[189] Accordingly, standardisation work is disciplinarily organised and dominated by industrial experts who can and have good reasons mobilising resources for this sort of 'investments in form' (Thévenot, 2009). Since their goal is to develop a universally applicable and scientifically correct guideline for road lighting, the standard is necessarily abstract and does not account for the concrete planning and installation of LED lighting in public, which brings us back to the more complex realities of cities.

4.3.3 Urban regeneration: New approaches and city competition

Public lighting is not only a burdening light-technological task but is increasingly being rediscovered as a means of urban regeneration. In some places, policy makers perceive the modernisation of public lighting technology not only as a low-interest subject and infrastructural problem but as an investment in the public image of their cities. The subject lends itself to this objective. Artificial lighting has an overwhelmingly positive connotation. In the past (see appendix 9), public illuminations and light spectacles, including the display of new technologies, were generally received with enthusiasm or even awe and perceived as a sign of progress and modernity (Binder, 1999; David E Nye, 1996; David E. Nye, 1990). Already before Industrialisation (9.1), the introduction of public lights has always also served political functions, including the representation of power or wealth (Koslofsky, 2002; Schivelbusch, 1987) and city competition (Stobart, 2002). Especially the last aspect seems to have gained in relevance in the 'post-industrial' city of the 21st century (cf. Eckardt & Morgado, 2011; Schulte-Römer, 2011a).

Since the 1990s, light planning has emerged as a new and popular policy instrument used for regenerating urban spaces and city branding. This new concern for the look and feel of the night-time city can be understood as a turning away from 'functionalist' public light planning. Not only traffic and personal safety matter, but also the aesthetic appeal and atmospheres of urban spaces (cf. Hasse, 2006, 2007c; Löw, 2008).[190] Images of illuminated skylines are as

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[189] In the revision of the standard for lighting in workplaces, current research in medicine, psychology and biology on the circadian rhythm and the human eye were taken into account (cf. Schulte-Römer & Onur, 2014).

[190] The increasing relevance of aesthetic issues and atmospheres are also reflected in an increased social-scientific interest in the nocturnal side of cities, night-time economies and urban regeneration. To name but a few: The geographers Timothy Edensor and Steve Millington offer interesting insights on festivals of light and the socio-cultural dimension of light and darkness (2012; T. J. Edensor & Millington, 2009a, 2009b), Scott McQuire explores city lights and architecture from a media studies perspective (2005, 2008), the geographer Jürgen Hasse explores urban atmospheres and criticises urban lighting practices from a phenomenological perspective (2006, 2007a, 2007c), the Berlin-based research cluster studied the value of artificial light, including commercial city lights, and natural darkness from economic, institutional and urban planning perspectives

impressive as daytime pictures. Festivals of light mushroom (T. Edensor, 2012, 2015) and attract night-time tourists or amateur photographers to perpetuate the live experience in glossy photographs.[191]

It seems that a 'culturalised' planning paradigm (cf. Reckwitz, 2009) has replaced the car-oriented 'functionalist' perspective, which dominated public lighting for the most part of the 20th century (9.3.3., Jakle, 2001; Mosser, 2007).[192] Urban planners have rediscovered the night-time city as a time-space that deserves expert attention and governance not only with regard to traffic safety but also with regard to economic, ecological and aesthetic potentials and exigencies of the night-time city (Brandi & Geissmar-Brandi, 2007; Narboni, 1995). The positive effects of these policies on the market for decorative LED lighting are obvious. The tiny, colourful and efficient diodes are the perfect light source for architectural or festive lighting. Yet contemporary integrated light planning can also affect the demand for LEDs in *street* lighting in at least two respects.

The first aspect relates to the urban scale and the redefinition of quality criteria and objectives. In the course of light planning, taken-for-granted 'matters of fact' can turn into 'matters of concern' and be renegotiated (Latour, 2009; Schulte-Römer & Hänel, 2015). In this context, the new notion of nocturnal urbanism, or *urbanisme lumière,*[193] refers to a more holistic approach to urban public lighting and open-ended policy-making that defines goals and procedures rather than the means and outcomes of light planning (Köhler, 2015; J. A. Schmidt & Töllner, 2006; Schulte-Römer, 2010). If this is the case, there is a chance that obdurate lighting practices are called into being and expert 'black-boxes' are opened. As we will see in chapter 5.3, the municipalities of Berlin and Lyon both developed new quality criteria for their public light planning, like the prevention of 'light pollution'.

(Meier et al., 2015). Only recently, a research group around Don Slater has started the research programme 'Configuring Lights' at the London School of Economics.

[191] During my participant observation during the Frankfurt Luminale, the Fête des Lumières in Lyon, or the Berlin Festival of Light, I found that these events attract amateur photographers who are equipped with tripods and sophisticated cameras and later distribute their night photographs in online communities.

[192] 'Car-friendly' lighting means that streets are lit primarily to suit the needs of car drivers who sit on their car seats and hence look from a lower perspective than walking men but who move faster through urban spaces—depending on the to traffic rules at 50km/h or 30km/h—and on roads.

[193] The notion of *urbanisme lumière* was promoted by French light planners in the late 1980s. For more information about the development and ideas of nocturnal urbanism in France and the concept of the '*schéma directeure d'aménagement lumière'* (SDAL) see Virginie Nicolas (2002) and Sandra Mallet (2011) and Roger Narboni for examples (Narboni, 2004, 2009).

Although debates on light pollution are as old as electric lighting (Hasenöhrl, 2015), the reduction of light levels is a rather new concern on the political agenda. So far, only few European countries, including France (since 2013) regulate light nuisance on a national level (Morgan-Taylor, 2015) or regionally, mostly on the initiative of civic interest groups (Meier, 2015). In this respect, light plans offer a new policy tool for addressing 'light pollution' as an ecological issue and *urban* matter of concern (Held et al., 2013; Krause, 2015).

The acknowledgement of rather new scientific findings about the ecological and biological impacts of light on humans, flora and fauna in public light planning is not at all irrelevant for the marketisation of LED lighting. Thanks to their directed light distribution and customisable light spectrum, LEDs can offer interesting new options in these respects and is advertised accordingly.

The second aspect relates to the external appeal of cities in a national or even global competition for attention and attractiveness. In this context, buzzwords like 'innovation', 'sustainability' and 'creative' come in handy. We have already seen that LED technology can make a contribution to culturalise and aesthetisise creative cities and their events. However, as it is also an energy-efficient novelty, it also suits 'innovative' or 'sustainable' city images. This might also explain why the driving forces behind the first installations of LED lighting were mayors rather than their lighting experts. 'LEDs are associated with energy saving. It's not necessarily true but… Thus, LEDs are installed and politicians communicate it', explained a French installer (2012-01-27, my translation). Such demonstration projects were carried out as early as 2008 when LED products were much less powerful and mature than in the six cases described below. Not surprisingly, the results were often problematic in light-technical terms.[194] On the other hand, municipalities won prizes for switching to LED lighting and greening their communes. Meanwhile, there are several awards or awarding schemes for sustainable lighting strategies, some of which are sponsored by manufacturers.[195] Berlin was awarded such a prize in 2009 in Lyon.

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[194] According to a French sustainability consultant the risk of too early adoption was greater in towns or villages than in big cities: 'You know that mayors don't know too much about lighting […] in small cities, they don't have the necessary technical people. Some mayors have put a lot of LED products in the street and after one year it was off. The LED products were out of order. Some of them called me so I have their feedback. You have to be careful' (sustainability consultant, 2011-12-15/16).

[195] The role of manufacturers in this political deployment of LED lighting seems to have been ambivalent. On the one hand they were happy to sell their products and promote them in real-life installations. On the other hand, they could also lose their clients' trust if their products did not perform well.

Another example that illustrates the important role of mayors and politicians particularly well is the above-mentioned competitive funding scheme for public LED lighting, which was part of the German SSL lead market initiative. As a German sustainability consultant explained, the call for projects was for both street lighting and decorative lighting installations with the aim to not only raise attention in civil engineering departments, but to also make an appeal to mayors who wanted to embellish the night-time image of their cities or communes (sustainability consultant (EU), 2012-28-11). Indeed, the competition raised attention well beyond the 'world of lighting', as projects were presented during trade fairs and conferences (BMBF, 2012-04-16; NSR, 2010-10-06, 2012-03-27/28/29, 2012-04-16). This brings us to my last point regarding the global environment of LED lighting.

4.3.4 Efficiency rules: The public understanding of LED light

In public discourses on LED lighting, its energy-efficiency can be considered as its defining feature. In the history of public lighting, this concern for energy efficiency can be considered as a rather recent development. As the geographer Jean-Michel Deleuil points out, energy consumption and the reduction of light levels only became an issue after the oil crisis in the 1970s (J.-M. Deleuil & Toussaint, 2000). And the sociologist Wiebe Bijker illustrates quite impressively how the energy-efficiency argument was ruled out by energy utilities in the 1930s when the first flourescent lamps were designed and marketed (1992). Instead, the innovation was publically presented as a daylight-like source.

Today, energy is precious and so are light sources that use less of it. As we have already seen, the installation of LED lighting is expensive but its potential as an energy-efficient light source are unquestioned. In the face of the global threat of a climate catastrophy (cf. Beck, 2007), efficiency arguments work particularly well in public and in the mass media. Our above-mentioned qualitative analysis of media reports on LED technology in France and Germany (3.3.1) showed that energy efficiency was the most used attribute by journalists to describe the innovation.[196] Other aspects like economic profitability, maintenance or other environmental issues were only mentioned second (Sørensen & Schulte-Römer, 2012).

[196] We have taken into account press articles on LEDs from the three most important daily newspapers in both Germany and France between 2002 and 2012. The comparative analysis was done with Atlas.ti by Sophian Sørensen during his internship at the WZB (Sørensen & Schulte-Römer 2012).

Furthermore, residents who are affected by LED installations in their streets seem to give more weight to the generally acceptable 'green' world of worth (cf. Thévenot, 2002) than to their subjective senses when they evaluate the new light in public (Besecke & Hänsch, 2015; Schulte-Römer, 2014a). For instance, a resident in Lyon explained that he had preferred the old lighting in his street but accepted and even appreciated the conversion to LED as the new technology was more sustainable (NSR, 2012-02-01). Another interesting observation was that lay people often relyon what they know about *domestic* LED products (cold white but very efficient) when they draw conclusions about public LED lighting. Yet things are much more complicated, as a Lyon light planner explained:

> 'Today there's this association 'LED = energy efficiency' […] so you only have to say you're using LED and the population is satisfied, even though it's not necessarily the right choice in every place, it's not the solution to everything. A poorly-used LED lamp can use up a lot more energy than a discharge lamp. And today when they say a discharge lamp is energy inefficient, be wary to ask which category, because the sodium lamp, after all, has been around since the 70s and is... super-efficient. We have yet to see a lamp come out with as much light efficiency as a sodium. And yet it's a forty year-old lamp […] That said, the fact that we can save energy with LED is true. Because we use them differently. We have a more localised source, we can illuminate *just* certain spots, and better allocate the light. But today, LEDs use up more energy for the same amount of lumens. And that, it not at all in people's minds. It's incredible' (DEP lighting engineer, 2012-01-06).[197]

Summing up, the public perception of LED lighting seems positively influenced by two aspects. First, it raises attention as an innovation and, in our 'innovation society today',therefore is *per se* and generally desirable—at least as long as nobody complains in public about undesirable effects. Second, the innovation is known to be energy-efficient and thus perceived as sustainable and almost unquestionably good. However, we have also seen that the situation can be much more complex from the technology users' perspectives (in the plural!) who are lighting our cities while mediating cost, energy consumption, light quality,

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[197] OV *« Aujourd'hui il y a cet association [LED=energy efficient] qui est créé qui est impressionnante, donc du coup la population peut être satisfait juste en lui disant on met la LED alors que ce n'est pas forcément le bon choix à chaque endroit, ce n'est pas forcement la réponse à tous les mots. Mal utilisé la LED, elle peut consommer plus d'énergie qu'une lampe à décharge [discharge lamp]. Et aujourd'hui, quand on dit, les lampes à décharge sont consommatrice, il faut se méfier de savoir quelle catégorie parce-ce que les sodiums [sodium], c'est quand même une lampe qui existe depuis les années soixante-dix et qui …est … super efficace aujourd'hui on n'a pas encore sorti de lampe qui a une efficacité lumineuse d'une sodium. Et pourtant elle a quarante ans cette lampe. […] Alors, après qu'on puisse faire des économies d'énergie grâce à la LED c'est vrai. Parce-ce qu'on les utilise différemment. On a une source plus ponctuelle on peut éclairer que certain endroit, mieux repartir à la lumière. Mais aujourd'hui la LED consomme plus d'énergie à quantité lumen égal. Et ça, c'est pas du tout dans la tête des gens. C'est incroyable »* (DEP lighting engineer, 2012-01-06).

public expectations, city image and urban atmospheres and their own uncertainties regarding the unproven technology. As my switching between specific examples and general observations has revealed, these *global* developments and issues have shaped *urban* realities. In the following chapter we will see how they mix and merge with local issues and developments in Berlin and Lyon.

5. Lyon and Berlin: Two extremes

In the previous chapters I have described the world-wide innovation activities around LED technology and developments in public lighting. In this chapter, I focus on public lighting in Berlin and Lyon. Again, my thesis is that LED lighting is installed and *enacted* site-specifically and in socio-material *urban public lighting networks*. I use the term 'networks', not only because it is in line with my analytical ANT-inspired approach, but also because it draws attention to the fact that these urban light-related arrangements of actors, artefacts, images and issues can expand beyond their cities or dissolve, as we will see in this chapter.

To begin with, I will offer a more general introduction to both cities (5.1). In line with my methodology, I limit my description to the information that was relevant or decisive for understanding public lighting planning: topography, urban night life and cultural events. Next, I will turn to the rather invisible side of urban public lighting infrastructures (5.2). We will see that the image of the City of Light and dark Gasopolis is also reflected in obdurate hard facts, for instance the number of light points per street kilometre. As already mentioned, these public lighting infrastructures are not only subject to technological modernisation but also politically negotiated and shaped by the cities respective light plans. Their particularities are sketched out in section 5.3. Finally, I will focus on the key actors in the urban public lighting networks of Berlin and Lyon (5.4). As we will see, the cities' public lighting services could not differ more in tems of their organisation and public-private collaboration.

5.1 A 'City of Light' and a dark 'Gasopolis'

Lyon and Berlin represent two extremes in urban lighting. Lyon is described as a bright place and referred to as a 'City of Light' (NSR, 2009-10-28). The Lyon lighting strategy and festival of light is internationally recognized as a model for city marketing and urban development (Gonzalez, 2010). Berlin, in contrast, might be famous for its night life but goes rather unnoticed in the world of urban light planning. If anything, it is renowned for its darkness.[198] However, Berlin was not always dark and Lyon not always bright. In fact, the public image of Berlin in the 1920s was that of an 'Elektropolis' (cf. Binder, 1999; Nentwig, Binder,

[198] When the Berlin light plan was presented the municipal team made explicit reference to Lyon, but as a counter example. The argument was that Berlin is dark and should remain that way to preserve the city's particular nocturnal atmosphere (NSR, 2011-04).

Bartmann, & Berlin, 2008). In the early 20th century, 'Berlin was amongst the best-lit cities in the world.' (Hasenöhrl, forthcoming). Home to important players of the electrical and lighting industry[199], it was a place where the benefits of the new electrical technologies and infrastructures were tested in public. Lay audiences enjoyed an unprecedented comfort in public lighting and an increase in commercial illuminations and festive displays (Binder, 1999; McQuire, 2008; David E. Nye, 1990).Until today, the early 20th century image of Berlin as a buzzing metropolis is closely linked to the new experience of electric lighting in urban spaces (9.3.4).

Lyon, in contrast, the rich, industrious third city of France once had the image of a 'black' city, making reference to the city's industrial and hence polluted appearance and its narrow alleyways and famous tunnels, the *traboules*.[200] According to a local politician,

> '…Lyon had a kind of tradition as this dark, sombre, mysterious, withdrawn city with its alleyways. When you enter a Lyonnais apartment, you go through side alleys with trashcans, and before you glimpse the lovely apartments, you start with the dark side...' (Marescaux, 2002).

The early 1990s mark a new start for both cities. Since then, the prosperous, rich and rather conservative Lyon has been reinvented by its city fathers in light and colour. In 1989, the political decision makers in Lyon set up two consequential top-down urban regeneration programs, including a *Plan Lumière* and a festival of lights, the Fête des Lumières. The same year, the Berlin Wall fell as a result of a bottom up 'peaceful revolution'. In the subsequent years, the city was transformed fundamentally. The public lighting service was privatised and the outdated infrastructures in both East and West Berlin became subject to large-scale refurbishment. But before we go into detail, let's have a more general look.

5.1.1 Urban geographies, topographies and built environment

Discussing city lights without acknowledging the material environment they illuminate is pointless. The geography of cities and their urban fabric are integral to the provision and perception of light in public spaces. Urban geographies and built environments suggest certain forms of illumination and forbid the use of others. Any lighting expert will take into account

[199] Like for instance Siemens, Osram and AEG (Stock, 2008-06-22).
[200] *Traboules* are small passages that tunnel the old buildings of Vieux Lyon and the Croix Rousse creating short-cuts and hidden connections between streets. They are a characteristic local feature and tourist attraction.

the particularities of surfaces, urban spaces, built structures and their usages when planning light in cities.[201] The question of what is appropriate lighting cannot be determined in theory but only with regard to a given spatial situation Accordingly, the Berlin Senate Administration explains to the Berlin parliament that lighting is adapted to the specific design of streets. Road widths and trees are taken into consideration as well as entrances to private premises, drain covers and parking lots. (Abgeordnetenhaus Berlin, 2008-07-14). In Lyon, the municipal engineers plan public lighting according to the European road lighting standard (EN 13201) but not without taking into account the materiality and uses of urban spaces (NSR, 2011-11-29a).

Lyon's urban topography is marked by its hills and rivers. Its urban structure nicely represents the different eras of its urban development. A roman amphitheatre is situated above the old town, a UNESCO world-heritage site. The streets in the medieval Vieux Lyon are narrow and linked by *traboules* that tunnel blocks of houses from the 15th and 16th century (see footnote 200). The Presqu'île, the political city centre between the Saône and Rhône*,* has the character of the Hausmannian city with boulevards, public confined public squares, grand residences and commercial streets. On the *rive gauche*, the 'left' side of the Rhône, a new economic city centre has developed around the central train station, *la gare Lyon Part-Dieu*, where high-speed trains leave from and to Paris, Marseille and a number of other European cities. As outlined in further detail below, the different quarters of the city, its river banks, centres and landmarks are also reflected and considered with special attention and site-specific treatments in municipal urban development and light planning strategies.[202] For instance, the rivers are treated differently in urban design. The Rhône is characterised as 'majestic', while the Saône is described as 'romantic', which is also reflected in the lighting designs for the river banks (Ville de Lyon, 2004).

As Lyon expanded eastward, it merged with the territories of neighbouring cities like Villeurbanne, Bron and Venissieux. In 1969, their municipalities joined forces as Grand Lyon, *Communauté urbaine* comprising 58 communes headed by the Mayor of Lyon. Since the need for orientation and safety in nocturnal urban spaces does not end at Lyon's borders, there is

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[201] In Los Angeles, the vast size of the urban territory even affected the choice of LED luminaires. As an employee of the *Bureau of Street Lighting* told me they preferred flat luminaires in small cases since they could load more of them on their vehicles and could thus save time and money during the installation. (OL & JQ, 2012-02-07)

[202] The lighting design for the different urban quarters and landmarks are further developed and technically specified in so-called Scema Directeur d'Amenagement Lumière (SDAL, see also 5.2.3.Cartier, 1998; Marescaux, 2002).

also a need for coordination in public lighting. In the past years, the Lyon expertise in lighting has radiated. Confronted with shared responsibilities, greater Lyon and its communes have redefined their collaboration in urban development projects, including light planning, and developed administrative procedures to share and divide responsibilities (Gonzalez, 2010).

With almost 500,000 inhabitants, Lyon is the third largest city and commune in France, after Paris and Marseille. The territory of 47,95 km^2 forms one commune that is subdivided into nine arrondissments . Size and population have an effect on the organisation of public lighting. Generally speaking, large cities can afford a municipal public lighting service, as is the case in Lyon (5.4.1), while smaller towns or communes rely on private services and expertise. Yet the size of cities is only a necessary, but not a sufficient condition. In Paris and Marseille, like in Berlin (5.4.2), public lighting services are provided by pivate partners.

Figure 5-1: Satellite images of Lyon (left) and Berlin (right) at night (CC).

Berlin, with a population of nearly 3.3 million, is Germany's biggest city and with a territory of 892 km^2 also its largest community.[203] In 1990, after reunification, the Land Berlin became one of 16 federal states. The city comprises several formerly independent towns and villages, all with their own centres.[204] After WWII the divided city developed in two different directions, with East Berlin as the capital of the socialist German Democratic Republic and West Berlin as an island within that state and with a special political and economic status.

[203] http://www.berlin.de/berlin-im-ueberblick/zahlenfakten/index.de.html, last access 2014-08-01.
[204] The former medieval merchant town and later electoral and royal residence literally gained ground over the centuries as surrounding towns became part of the city. In 1709, the former Elector and newly crowned king Friedrich I combined Berlin, Cölln, Friedrichswerder, Dorotheenstadt and Friedrichstadt to his royal capital and residence. In 1912, the city reached today's large territorial expansion when Berlin was united with the adjacent cities, among them the later districts Charlottenburg, Schöneberg, Wilmersdorf, Lichtenberg, Neukölln and Spandau. See http://www.berlin.de/geschichte/, 2013-09-10.

The material effects of the division shape Berlin's public infrastructures and night-time image until the present day: West Berlin is lit in white, East Berlin in yellow (Figure 5-1). The division is also still visible in the built environment. In the central areas of East Berlin, post-war urban designs carry the mark of socialist planning paradigms, which are most evident in the form of spacious public spaces, wider streets and prefabricated buildings, the so-called *Plattenbauten*. In West Berlin, the paradigm of the car-friendly city is reflected in some concrete structures. More generally speaking however, Berlin's built environment was most markedly shaped by the plurality of its districts and by the 19th century Hobrecht master plan, that determined the structure of the inner-city street grid and urban infrastructures and the height of Berlin's *Gründerzeit* architectures, mostly four-story tenements of 20 to 22 meters in height.[205] Today, both plurality and structure are reflected in a new urban planning approach which also builds the basis for the Berlin light plan (5.3.2). Based on geographical and 'life-world' oriented socio-statistical data, the city has been subdivided in urban planning areas, so-called LOR *(Lebensweltlich orientierte Räume)* with typical material spatial features.[206]

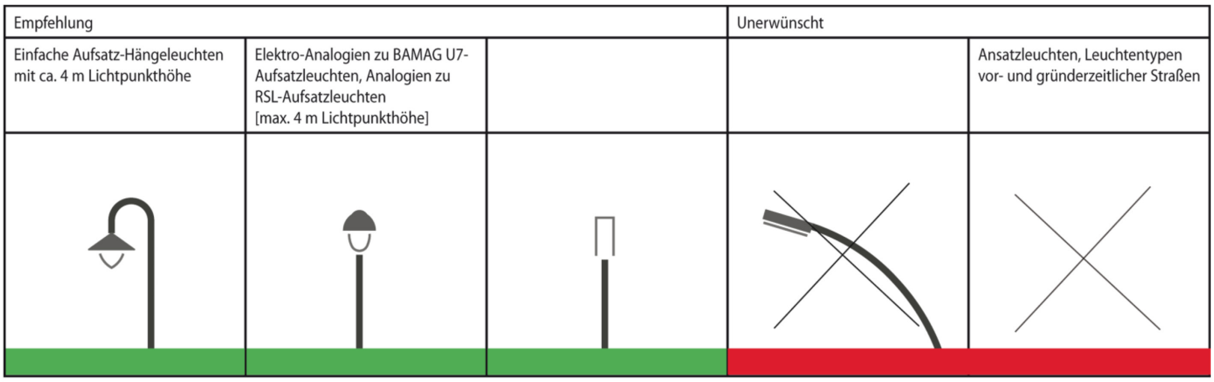

Figure 5-2: How to choose appropriate luminaires for Berlin (SenStadtUm, 2011, p. 51).

Another characteristic feature which also matters for public lighting are its voids, non-developed or natural areas. First, settlement and transportation spaces that require street lighting cover only about two-thirds of the Berlin territory. About one-third of the Berlin territory is covered by forest, water or green areas.[207] There are more then 2,500 park and recreation areas with a total area of 65 km^2, which are managed by districts and the Senate

[205] http://www.baunetz.de/meldungen/Meldungen-150_Jahre_Hobrechtplan_2622205.html, 2014-08-20.
[206] With the new approach https://www.statistik-berlin-brandenburg.de/Publikationen/Aufsaetze/2006/MS-BE_200608-01.pdf, last access 2014-08-01.
[207] According to the Berlin Senate website almost 7 per cent of the greater Berlin territory is covered by water and about 18 per cent is forest area http://www.berlin.de/berlin-im-ueberblick/zahlenfakten/index.de.html, last access 2014-08-01. However, the forest administration states that they cultivate even 290 km^2 of forest land. http://www.stadtentwicklung.berlin.de/forsten/index.shtml, last access 2014-08-01.

Administration.[208] Second, the division of the city and the Berlin Wall in its concrete materiality first created and then left a strip of void spaces and surrounding waste land and run-down buildings and structures that also contribute to Berlin's unique look. Yet while Berlin's past division is an administrative challenge, it also contributes to the city's look, feel and image[209] as a historically interesting and culturally exciting place.

5.1.2 Urban nightlife

Urban nightlife and city lights are closely related and have co-evolved in the history of urban lighting. The commercial lights in city centers have paved the way for public lighting infrastructures. The nightlife of cities gives them a unique rhythm that defines and distinguishes their urban quarters and internal dynamics. In times of LED lighting these city-specific dynamics gain importance, as adaptive lighting offers the possibility to adapt public lighting site-specifically to the nightlife in different urban quarters. So far, public lighting is still planned and installed in standard ways to facilitate mobility and enhance a more general sense of safety in public spaces after dark. That means that the lights are switched on city-wide at a certain hour, in winter earlier than in summer, and switch off at dawn, notwithstanding the actual night-time activities in urban spaces and independent of existing commercial or private light sources. This might change in the future. In 2014, innovative 'intelligent' approaches are as yet in an exprimental stage.[210] I will therefore only briefly sketch out the most obvious differences between the nightlife in Lyon and Berlin.

The reunified Berlin has developed into a poor and poorly-lit city that is famous for a flourishing informal night-time economy. It is reknowned as being poor but attractive.[211] Its reputation for alternative life-styles and creative scenes links both characteristics to a powerful image of a transforming city.[212] Over the past years, the German capital has acquired

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[208] http://www.stadtentwicklung.berlin.de/umwelt/stadtgruen/gruenanlagen/, last access 2014-08-01.

[209] The image is more than fiction. It also builds on facts, especially cheap rents and living costs, numerous attractions. Furthermore, the city's eventful history is exhibited and re-enacted (cf. Frank, 2009).

[210] For example, in Eindhoven an intelligent lighting system is currently being tested in a popular party street. The system uses various sources of information (weather, police, social media and event calendars) to adapt the lighting to the atmosphere in the street. If necessary, the light levels can be dimmed or increased to have a relaxing or de-escalating effect (cf. Schulte-Römer, 2014b).

[211] The link between Berlin's extreme indebtedness and attractiveness was famously coined in 2003 by the Ruling Mayor Klaus Wowereit who made the news by describing his city in an interview as 'poor but sexy' (http://www.focus.de/politik/deutschland/wowereits-berlin-slogan_aid_117712.html, last access 2014-01-05).

[212] Transformation and renewal are driven by multiple actors, including politicians, private investors, citizen initiatives and so-called creatives, and can take very different directions and shapes. However, 'creative Berlin' should not be confused with creative governance approaches (Merkel, 2012).

the image of an exciting tourist destination and party town. A vibrant night life and club scene contributes to this image and turns Berlin into a city that is marked by a plurality of day and night rhythms, with places that never sleep as well as calm residential areas. The night-time uses of public spaces coincide with commercial illuminations including ambient illuminations and commercial lights in shopping zones and entertainment districts.[213]

In this respect, the contemporary Berlin nightlife shows special features. In some districts, the so-called '*Spätis'*, little shops selling snacks and alcoholic drinks until the early morning hours (Klier, 2013), are characteristic for the 24/7 urban buzz in some areas. They can be considered as key institutions of a localised party infrastructure and low-budget party night-time economy that 'turns the street into a bar' (Hollersen & Kurbjuweit, 2011). Furthermore, an alternative party scene and landscape has emerged in the changing urban spaces during the post-reunification years. It still flourishes in basements, bunkers in disused factories, breweries or transformer buildings, in industrial areas and by the Spree River. Situated on unused properties, these alternative party locations are off the map of public lighting and often extravagantly illuminated.[214] Abandoned places offer party makers black screens in the literal sense to experiment with extraordinary illuminations and light effects. The alternative Berlin party scene thus sticks out as an urban zone unaffected by institutionalised lighting practices and marked instead by dark areas and improvised creative lighting schemes.

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[213] Private commercial lights can also turn into public issues. A recent Berlin example is the controversy over a bright media façade on the Spree River, which caused residents to complain about the light nuisance and led to an administrative intervention (Krause, 2015).

[214] An article in the German weekly news magazine *Der Spiegel* offers an exemplary description of Berlin as an 'overstrained city', a nocturnal place of moving party zones (Hollersen & Kurbjuweit, 2011, p. „Die überreizte Stadt"). The two authors describe Berlin night life as a myth: 'Nights in Kreuzberg have long been unbridled but they were also political, avant-garde and individualistic', adding up to the myth. It was fostered by the post-reunification club culture of the 1990s and is reaching its present culminating point in world famous locations like the Berghain or the offshoot of the legendary Bar 25, the club Kater Holzig by the Spree River. The journalists describe it as 'a place that picks up on the Berlin myth and takes it further.'

Figure 5-3: Urban nightlife on the Spree (CC) and on the Rhône ©.

In contrast to the 'Berlin party 24/7', Lyon is busy on weekends but rather calm from Monday to Wednesday. On Fridays and Saturdays it is difficult to find a table in bars or restaurants. In contrast to the German party capital, the third city of France has a reputation for rather tasteful evening entertainment. Lyon is famous for its traditional cuisine and local specialities, which are served in so-called *Bouchon Lyonnais*, authentic restaurants situated primarily in the medieval Old Town (*Vieux Lyon*) and in the city centre on the *Presqu'île.* There is also a high density of cinemas and theatres in line with the local puppet theatre and film traditions.[215]

The bourgeois spirit of Lyon's night-lilfe also reflects in curfews and drinking regulations. After 11pm, only licensed bars serve alcoholic drinks. In July 2011, the city of Lyon introduced a ban on alcohol sales between 10pm and 6am.[216] Of course, there is not only *one* bourgeois night-life culture in Lyon; night-time activities vary according to age, social background, income and occupation.[217] Drawing on interviews, curfew regulations, literary and historic accounts and observations, the Lyon-based human geographer Jean-Michel Deleuil analyses the changing temporal and spatial orders of «*Lyon la nuit*» ('Lyon at night') and outlines the city's weekly rhythm and night-time image. Deleuil describes how residents

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[215] Puppet shows involving the so called *Guignol*, a comic puppet hero, are another local specialty dating back to the early 19th century when puppet satire became a popular form of entertainment among the *Canuts*, the Lyon silk workers (source: http://www.de.lyon-france.com/Geschichte-und-Kulturerbe/Guignol, access date 2013-07-09). Cinemas relate to the local pioneers in photography and film, the brothers Lumière, who lived and worked in Lyon in the late 19th century.

[216] http://www.lyoncapitale.fr/Journal/Lyon/Actualite/Actualites/Securite/Vente-d-alcool-apres-22h-Et-pourquoi-pas-un-couvre-feu, also: http://www.guardian.co.uk/world/2011/jul/17/lyon-reduce-le-binge-drinking, a similar policy applies in Mannheim.

[217] The people who visit restaurants and bars during the week are not the same ones who go out on weekends. As the former spend more money, they are the preferred guests in the Lyon night-time economy, reports Deleuil(1994, p. 73).

engage affectively with singular quarters of their city, for instance in the course of night-walks, and experience district-level urban transformations from their night-time perspective.

Like in Berlin, different quarters and districts have their own weekly rhythms, their own actors and audiences. On weekends, the narrow streets of Old Lyon are crowded with visitors and young people.[218] The *Croix Rousse*, meanwhile visibly marked by gentrification processes, is still a popular nocturnal place and destination, with groups of young people gathering on the slopes of the hills with live music, bottles of wine and beer, cigarettes and spliffs (see case 6.3, NSR, 2013-06-26a). Furthermore, the regenerated and illuminated river banks of the Rhône (Figure 5-3) have become a popular sports and meeting place. The mundane experience of nocturnal Lyon stands in contrast to the extraordinary celebration of the night-time city during the Fête des Lumières.

5.1.3 City images as special local features

There is no one way to look at a city. Nevertheless, urban planning and development, just like light planning, depend on coherent images and future visions. They can enhance or hamper processes of urban renewal (Hommels, 2005b)—and also the introduction of innovation, as we will see below.

To mobilise a specific image or future vision is a distributed and constructive activity that builds on what exists and also creates something new (cf. Löw, 2005). City images are based on the actual experience of urban spaces and are also shaped by cultural representations or enactments. In this respect, the cultural sociologist Andreas Reckwitz observes a tendency towards a 'self-culturalisation'— an aesthetisation of urban places in architectural design, city marketing and events that facilitate the political or economic exploitation of local cultural assets (Reckwitz, 2009).[219] As such, culturalisation can be understood as a reflexive practice that has a semantic, material but also a pre-reflexive sensory dimension, and evokes specific readings of a city's history and tradition.

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[218] Having lived in *Vieux Lyon* I found that getting home through the crowded streets of the old town could be troublesome, especially when one of the brilliant Lyonnais street bands played on the square in front of my door.
[219] Night-time histories of European cities relativise Reckwitz' socio-cultural diagnosis. As mentioned above and outlined in more detail in chapter 9, public lights have always been both, a means of securing public spaces after dark and a means of self-culturalisation in the hands of privileged or powerful actors (see also Ekirch, 2005; Koslofsky, 2011; Schivelbusch, 1988; Stobart, 2002).

Looking at Lyon and Berlin, two such light-related culturalised features stick out. Interestingly, they are mobilised by different groups of actors. While the official vision of Lyon as a 'City of Light' is promoted by the local government and municipal administration, the notion of the 'Gasopolis' Berlin is mobilised bottom-up by a local protest. In both cases, the actors promote their preferred city images with reference to unique socio-material settings and local traditions.

The Lyon Fête des Lumières

Once a year, Lyonnais, and millions of tourists and visitors from neighbouring cities and villages and from afar crowd into Lyon when the city lights up around December 8th for the world renounded, four-day festival Fête des Lumières. Masses of spectators move through the centre and explore new territories as the *Fête* transforms familiar places and raises the spectators' interest in unfamiliar corners and areas. It interrupts the normal district-level Lyon night life and creates a state of exception that seizes the whole city. Lyon's international public image as an attractive city and tourist destination heavily draws on the nocturnal spectacle.

The festival combines local catholic tradition and city marketing (Djaoui & Poirieux, 2007). Born from a medieval catholic tradition, the first celebration of lights dates back to 1852 when the Lyonnais lit candles in their windows and on the streets to celebrate a long-awaited inauguration of a statue of the Virgin Mary on the day of the Immaculate Conception.[220] In the 1980s the religious event had become less important but was reinvented by the City of Lyon in 1989 as part of its concerted lighting policy (5.3.1). The one-day religious celebration was expanded to a four-day event and became marketing tool. When the festival became more and more important, a municipal team was installed to organise the event and prepare the city for the masses. Since then, the Fête des Lumières has become the annual flagship event of the 'City of Light' Lyon, which ancient name Lugdunum is also associated with light.[221]

[220] Since 1643, the Lyonnais have thanked and celebrated the birth of the Virgin Mary each year on September 8th, for having spared the city from the pest. In 1852, when a statue of the Virgin Mary was supposed to be inaugurated, the celebrations were delayed by bad weather and postponed to December 8th. When the day of the long-awaited festivities began with a storm and the heavy rain finally ceased so that the procession could take place, the Lyonnais lit candles in their windows creating a memorable spiritual event that has benn repeated every 8th December since then (Collomb, Buna, & Bouchet, 2009?; Djaoui & Poirieux, 2007).
[221] Lyon was founded in 43 B.C. as the Gallic city Lugdunum, a fortified place dedicated to the Celtic god Lug. One way to interpret the name of the God is to associate it with flashing light (from Proto-Indo-European *leuk): The shiny One or the Shadowy One. Another is to associate it with ravens that appear in a founding story by

The appeal of the festival results derives from its large-scale light projections and spectacular dimension. The Fête des Lumières has transformed into a laic event without cutting its religious roots. The Virgin Mary is still worshipped but simultaneously it is also a celebration of the city and the actors who make the annual spectacle possible: the municipality, the church, shop keepers and commercial actors and the energy supplier EDF (J.-M. Deleuil, 1994, p. 119). Thus, the festival is also 'display of virtuosity' (Collins, 1988)—for organisers, lighting designers, light media artists and technicians.

The festival unfolds its appeal against the backdrop of the city's ordinary night-life. According to its organisers, it allows citizens to rediscover their city by highlighting the diversity of the districts and by encouraging new forms of perception and routes of access (Marescaux, 2002, p. 151). Large scale projections on the facades of 19th century houses on the *Presqu'île* draw the masses, smaller and more poetic installations invite visitors to take a rest on the fringes of the spectacle or to follow the lights into neighboring areas like the Croix Rousse, the *Berges du Rhône* or the 7th arrondissement on the other side of the Rhône.

The Fête des Lumières is an event for tourists and Lyonnais, young and old, visitors and vendors. As such, it is an important economic factor. Shop keepers make the business of the year, hotels are sold out and beds are booked up to one year in advance. Citizens profit from it as visitors, street vendors or by letting their rooms to tourists. But there are also critical voices who preferred the more intimate traditional *fête du 8 décembre*. Some residents leave the city during the festival to escape the masses, to escape the loud music that accompanies the spectacle, or because they reject its commercialisation (Schulte-Römer, 2011-12-10).

One can conclude with Tim Edensor (2015) that the ephemeral event shapes the perception of the night-time city in a twofold way: On the one hand, the light projections and illuminations transform and de-familiarize particular urban spaces of Lyon. On the other, they promote an extraordinary and collectively shared experience of the city as a whole. The round walks suggested by the festival organisers add to the extraordinary experience. The hills of Lyon offer various panoramic views that make Lyon comprehensible as a whole.[222] The sensory and semiotic effects generally apply to light events, including the Festival of Light in Berlin.

Plutarch where they are described as a good omen to settle in the place at the Saone. However the name came about, today it suits marketing strategies for the City of Light.

[222] For the relationship between panoramic views and the perception of or control over cities see (De Certeau, 1984; Defoe, 1991; Scholz, 2004).

Figure 5-4: Lyon during the Fête des Lumières (CC).

In Berlin, the Festival of Lights is one event among others, and privately organized. Since 2004, the event is held every year in October. With regard to the city's image and marketing, it is far less important than the Fête de Lumière. While both festivals literally produce night-time images of their cities in the form of fotographs and media reports, their effects on the innovation activities on LED lighting are very different. In contrast to the Lyon Fête des Lumières, the Berlin Festival of Lights has little or no effects on municipal public lighting strategy and innovation activity, as will be further outlined in chapter 7. Instead, the public lighting situation in Berlin is affected by the 'culturalisation' of the Berlin gaslight infrastructures.

The Berlin Gasopolis

The gas lighting infrastructures in West Berlin are a relict from the 19th century. They were established in the course of the city's industrialization (9.2.1). Today they are outdated and expensive to maintain. The technology is no longer being further improved and there is no market for gas lighting technology in Europe. Berlin therefore imports the little gas sockets that glow inside the gas luminaires from India.

Presently, the dismantling of Berlin's gaslights is underway—the details will be outlined in my case study on Saalestraße and Falckensteinstraße (6.2.2). The electrification is a cost-intensive endeavour. It involves underground work, the deconstruction of gas infrastructures and the connection of every individual light point to the Berlin electricity grid (NSR, 2012-07-16). The Senate justifies the high cost of the infrastructural project by pointing to the extremely high maintenance and energy cost and the short armortisation periods of the electrification project.[223] Nevertheless, the lighting engineers see themselves confronted with strong public opposition. The Berlin gaslights have achieved a sort of cult status in the course of a civic protest against their destruction. The local and national press have reported about the issue. The argument against the electrification of Berlin's public lights is essentially a culturalist one: The friends of the gaslights argue that the universal industrial logic of cost-benefit analyses should not apply to a unique territorial monument (*Flächenmonument*) of historical and cultural value.

Figure 5-5: The Berlin Gaslight Museum in Tiergarten (CC).

With half of the world's remaining gas luminaires, Berlin is considered the largest contiguous gas-lit area world-wide. Pro-gaslight protesters therefore claim that Berlin's outdated lighting infrastructures should be protected and preserved as a world heritage. Their public campaign visibilises and redefines the value of the public lighting infrastructure. The technical rarity is

[223] Before the conversion, SenStadtUm stated that the 44,000 Berlin gaslights consumed an annual amount of energy that was equivalent to the annual energy consumption of 180,000 electric light points (SenStadtUm, 2011, p. 18). In addition, the gaslights were disproportionally expensive to maintain and hence difficult to operate (source: public presentations).

thereby redefined as a cultural and political artefact. As we will see, this revaluation is also consequential for the introduction of LED lighting in Berlin.

Looking back in history, the Berlin gaslights were already a political issue when they were built and still perceived as a technical innovation. The first gaslights in Berlin were installed by the British Imperial Continental Gas Association (I.C.G.A.) in 1826 (Grimm, 2012, p. 22). In 1847, the Berlin gasworks were communalised. In the late 19th century Berlin's electrical industry started to push for the electrification of public lighting, initially against municipal interests.[224] Eventually, the electrical industry's innovation activities were successful and the Edison Gesellschaft, later Bewag, started to electrify Berlin together with the city's electrical industry. However, gas infrastructures remained. Until Worl War II, 88,000 gas luminaires lit Berlin's streets. After the war, almost 99 per cent of them were destroyed (Grimm, 2012, p. 27). In the post-war years, the rebuilding and repair was first hampered by a shortage of material and then by the 1948/49 Berlin Blockade.[225] At first, gaslights were rebuilt in all sectors. The ones in West Berlin remained. In East Berlin, the technology was not further modernised. In the 1960s and 1970s the socialist government dismantled them and switched to more efficient, then up-to-date electric lighting technology (Grimm, 2012, pp. 31-34; Hasenöhrl, 2015).[226]

Meanwhile, in West Berlin, gas lighting was maintained and technically optimised by Gasag, despite the ongoing technical controversies, despite the availability of more efficient electric light sources[227] and despite the enclave's urban development into a car-oriented city. This obduracy can be considered as an effect of both economic considerations and cultural

[224] Around 1900, the Berlin municipality was reluctant to introduce electric lighting since it had stakes in the local gas utilities (Hasenöhrl, forthcoming; Thomas P. Hughes, 1983). The same applied to Lyon (J. M. Deleuil, 1995, p. 59). Yet, the local electrical industry players found allies. Especially commercial actors were interested in illuminated shopping streets and promoted the electrification of their cities (see 9.3.2). A hundred years later however, the obdurate Berlin gaslights show that the penetrating power of this so-called disruptive technology is not the same everywhere.

[225] At first, only electricity was rationed in West Berlin while gaslights were still working. When coal supplies were exhausted, West Berlin went dark (Grimm, 2012, p. 28) (Grimm, 2012: 28). In September 1948, the US military government cut the gas lines through which the Berlin gasworks in the west sector supplied the sowjet sector. In March 1949, West Berlin had its own gasworks Gasag (Grimm, 2012, p. 31).

[226] Hasenöhrl explains: 'In the post-war period, East and West went separate ways concerning the reconstruction and development of street lighting. East Berlin almost completely abandoned gaslights since the 1960s because of the defective condition of its infrastructure and the planned conversion of its gas industry to natural gas, which made it impossible to turn out street lights during this time. In 1977, the magistrate decided on the abolition of all gas lamps. This resolution, however, was never fully implemented (especially in the district Köpenick).' (Hasenöhrl, 2015)

[227] 'It was not until the Second World War with its massive destruction of lighting infrastructures and power stations that electricity prevailed in Berlin as the primary source of lighting. This development was fortified in the 1950s and 60s when cost-efficient fluorescent lamps and high pressure mercury vapour lamps became ready for the market.' (Hasenöhrl, 2015, p. 110).

reflections. The infrastructural investments associated with the transformation were high and the 'nostalgic' value of gas-lit residential streets seemed priceless. In addition, the West Berlin civil society began to campaign against the demolition of its gaslights in the 1970s (Hasenöhrl, 2015). Another popular political explanation is that the city under siege chose to minimise its dependency on electricity infrastructures and on supplies that could be blocked by the surrounding socialist state and, therefore, chose to rely on its own gasworks.

Against this background, the Berlin Parliament decided in December 1989 to preserve the gaslights as part of West Berlin's urban identity (Grimm, 2012, p. 31). In the 1990s however, the debate was back on the political agenda. In the face of Berlin's restructuration and debt, the disproportionate energy and maintenance costs of the outdated technology no longer seemed justifiable. In 2007, after fierce political debates, the Senate passed a new public lighting strategy, which included plans to electrify West Berlin, and the parliament gave its consent (Abgeordnetenhaus Berlin, 2007-09-13). Since then, the protest against the demolition has been ongoing. The friends of the gaslight highlight the uniqueness of the nocturnal urban ensembles and refer to the history of the 'Gasopolis' Berlin as a counter narrative to the more common notion the 'Electropolis' (Grimm, 2013-11, p. 29) (cf. Cicero, 2012-06; Dame, 2011).

Two pro-gaslight associations actively shape public discourses, organise protests and disseminate information about the Berlin gaslight history and present politics. The most active group, the association for 'gaslight culture' Gaslicht Kultur e.V., meets regularly (NSR, 2012-11-14a). They also give public presentations and offer guided bus tours through gaslight ensembles in the Berlin district of Charlottenburg in order to show and explain the variety of the historic technology to fellow citizens and tourists, and to generate their enthusiasm for the beauty of its warm and soft glow. The association has successfully assembled new allies around the issue and joined forces with local tradition associations as well as Europa Nostra, the self-appointed 'Voice of Cultural Heritage in Europe'. They also found prominent supporters in the Berlin cultural establishment, including publicists and stage performers, who actively support the protest against the electrification in public events or in the media (cf. Schulte-Römer, 2014a). The protesters also organise demonstrations, physically prevent dismantling with sit-ins on the construction sites, and write open letters to the Senate and the Ruling Mayor of Berlin. Last but not least, the Berlin gaslight friends are also knowledgeable amateurs in the positive sense of the word (Hennion, 2004).[228] The have developed and embodied an expert vision, publish articles on gaslight (see Grimm, 2012) and cooperated with the municipal Berlin department for monument protection. Together, they worked out a zoning plan which marked the most relevant gaslight protection zones. The proposal formed the basis for the gaslight amateurs' and preservationists' negotiations with SenStadtUm and resulted in an agreement to preserve 5 per cent of the total gaslight infrastructure.[229]

The civic pro-gaslight movement thus promotes a historically informed, cultivated and culturalised image of nocturnal West Berlin, which was also widely recognised and reproduced by local and national newspapers. The gaslight amateurs' cultural-heritage campaign is also innovative in the sense that it aims to safeguard not only the materiality of the historical technical artefacts but also the *immaterial nocturnal atmosphere* they associate with gaslight. 'Can light become a monument?' asks a local journalist (Bernau, 2012-03-31). Apparently yes: Europa Nostra argues that gaslights are outstanding 'witnesses of the industrial era' just like gasworks and buildings of that era and as part of a unique ensemble. 'In several neighbourhoods of Berlin both the gaslighting and the buildings were constructed in the same period, constituting an identity ensemble of the urban landscape' (Europa Nostra, 2013-05).

To conclude, the cultural revaluation of gas lighting is not only a matter of *technology* but also a matter of *light quality*. The debate draws attention to the light temperature and light colour of gaslight, levels of brightness in urban spaces as part of their authentic look and feel. But city images and culturalised political representations are only the publically *visible* side of public lighting decisions. The *invisibilised* urban infrastructures, in contrast, are also or even more crucial when it comes to understanding path-dependencies and innovation in public lighting. As we will see in the following section, these include light technical equipment, i.e. luminaires and light sources, on the streets as well as larger technical systems like energy grids.

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[228] In line with the historic roots of the term and Antoine Hennion's sociological concept, I refer to them as 'gaslight amateurs' because they are 'lovers' of gaslight and have acquired a profound knowledge of both the politicised socio-technical system and the gas technology.

[229] The compromise did not resolve the conflict. On the contrary, the gaslight amateurs blame SenStadtUm or the contracting firm for destroying the most beautiful gas-lit urban ensembles first—out of ignorance or even on purpose. For the amateurs the intactness of these ensembles, e.g., in Charlottenburg, is crucial as they use them as an urban museum for their gaslight bus and bicycle tours.

5.2 Invisibilised but pervasive material infrastructures

Urban infrastructures shape city images and our cultural perception of light. Compared to festivals and cultural heritage they are little talked of in public as long as light levels and light colour remain unchanged. They are nevertheless pervasive in LED installation processes because they present the hard facts on the basis of which lighting engineers plan and evaluate the new technology. From an expert perspective, the key evaluative criteria are efficiency, light quality and compatibility. They are all three relative. LED offers great potentials, but there are still comparably efficient light sources. The quality of installations not only depends on the product but also where and how it is installed. Finally, the most sophisticated technology is worthless if it is not compatible with existing equipment and routines. Lighting professionals who have no stakes in the LED business therefore never forget to point out that the innovation is not generally and always better. If it is an improvement or not depends on what is and was there before. In this section, I provide a glimpse of the existing lighting equipment and infrastructures in Berlin and Lyon and beyond.

5.2.1 Light levels revisited: The infrastructural explanation

The difference between bright Lyon and dark Berlin is also manifested in the cities' urban infrastructures. The 523 street kilometres in Lyon are lit by approximately 51,400 street lights (Ville de Lyon, 2011, p. 5). In Berlin, approximately 220,000 luminaires illuminate 5419 street kilometres.[230] In other words, the ratio of lights per street kilometre is nearly 41 in Berlin and 98 in Lyon.[231] The average ratio of light points per inhabitant is equally different: In Lyon, one light shines per nearly 10 inhabitants. In Berlin the ratio is one to 15, although the population density in Lyon is 2.5 times higher than in Berlin.

The bright streets of Lyon and the dark zones in Berlin, however, are not isolated cases but match a more general pattern. A Lyon lighting designer explains that in France the whole countryside is lit while in Germany they have just a few lamp posts now and then. 'In Berlin like in Frankfurt, I imagine generally in Germany, the light levels are really low' (Lyon

[230] Source: http://www.berlin.de/berlin-im-ueberblick/zahlenfakten/index.de.html (state as of 2012).
[231] The average ratio in France is 35 light points per kilometre (metropolitan France including rural areas) (AFE, 2013). In addition to these functional lights, the Lyon DEP also operates and maintains more than 2000 stadium lights and more than 15,000 decorative lights, e.g., the illumination of fountains (Ville de Lyon, 2011, p. 5).

lighting designer, 2012-01-09, my translation).[232] According to a German consultant (2012-28-11), 80 per cent of the German communes do not comply with the performance standard for road lighting, the DIN-EN 13201.

However, the cultural argument also has a material technological side to it. A recent comparison (see Table 5-1) between France and Germany supports the claim of different light levels (AFE, 2013). Although there are more light points in Germany, the total electricity usage for public lighting and its share of the global energy consumption is significantly higher in France—despite the country's smaller population. Since the lighting technology used in European countries is comparable in terms of efficacy and design, one can conclude that populated areas in France are generally more brightly lit than German cities and communes.

Total and relative figures[233]	Germany	France
Light points	9,500,000	9,000,000
Energy consumption	4 Twh	5,6 Twh
Average share of public lighting in the municipal electric energy bill	0,7 per cent	1,4 per cent
Average connected load per light point	80W	165W (including electric apparatus) [234]

Table 5-1: Public lights and energy consumption in Germany and France (source: AFE 2013).

Explanations for the difference in light levels fall into two categories. One line of argument promotes a cultural explanation. A number of lighting professionals I met and interviewed referred to a general 'fear of darkness' in the south of Europe. A French lighting designer (2012-01-09) explained: 'The Germans are not afraid of blackness […] The French fear the darkness,' He then suggests that there might be a link between the thrifty use of light in Germany and the sober Protestantism that has shaped German culture since the reformation. A manufacturer associates the difference with contemporary night life and nocturnal cultures. In

[232] *«… effectivement à Berlin, comme à Francfort—j'imagine en Allemagne d'une manière généralisée—il y a un niveau d'éclairement qui est vraiment bas»* (Lyon lighting designer, 2012-01-09)

[233] The comparison is based on data from ADEME, EDF, AFE, Syndicat de l'Eclairage, Philips and Osram. A German survey (PWC & WIBERA, 2010) provides more detailed informationen. Yet I also gathered contradictory information. A French expert told me that the average connected load in France is only 130W per light point.

[234] In 2004, when electricity prices were still low (€0,0757/kWh), the average connected power of a Lyon street luminaire was 180 kWh.The average connected power of all 62,297 light points, including decorative, sportive lighting and lamps in telephone booths, clocks, etc., was 207W adding up to a total installed power of 13,488 kWh. Not surprisingly, the high power illuminations of sports areas like football fields consume the most (on average 713kWh/luminaire), raising the average connected power of the total amount of light points in the city (calculation based on DEP, 2004).

the South, so his argument, people meet outside on the streets at night to socialise. They need lights to look each other in the face and recognise their friends.[235]

The infrastructural explanation links the bright French cities to the national nuclear industry (Lyon lighting designer, 2012-01-09; telemanagement expert, 2012-01-26). Indeed, the 58 French nuclear power reactors have made the illumination of urban spaces comparatively cheap. In the past, communes have benefited from low night-time electricity rates.[236] In 2003/2004, the City of Lyon paid an average of €0.0757 per kWh (DEP, 2004). In the past few years, the situation has changed and electricity prices have risen dramatically to almost €0.12 per kWh in 2013 (personal communication, 2014-01-07). Nevertheless, with a rate of around €0.15 per kWh, German cities still pay around 25 per cent more for their electricity supplies (NSR & Toschka, 2013-05-29).[237] Thus, energy-efficient lighting does not have the same financial effects in Berlin and Lyon.

Yet the number of luminaires and cheap energy do not automatically result in brighter or darker streets. Instead, light levels also depend on the material urban environment, light sources and luminaire designs. Urban spaces are naturally darker if surfaces are dark and swallow light instead of reflecting it and trees or facades absorb the light of street luminaires. In terms of lighting equipment, three factors are particularly important, the pole distances and height, the light output of luminaires and their age: If poles are high and stand at large intervals, the light will diffuse and more powerful light sources are needed to illuminate well. Light outputs depend on the light sources, the luminaire design and the reflector or optical system (see 4.1). Finally, most street lights, including LED luminaires, get weaker over time.[238] The older they are the less light they give.

Lyon and Berlin differ with regard to all three factors. Regarding the pole distances, the initially mentioned figures suggest that the Lyon light points are positioned much closer to

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[235] The argument resonates with Mikkel Bille and Tim Flohr Sørensen's observation about the connection between Danish sociability, hospitality and islands of warm light surrounded by darkness (Bille & Sørensen, 2007).

[236] http://www.world-nuclear.org/info/Country-Profiles/Countries-A-F/France/, last access 2013-01-06.

[237] These figures are based on my own inquiries and expert estimations since I could not find robust comparative data. A pertinent EU report on public lighting in Europe does not provide comprehensive data on that question. An expert inquiry resulted in a short incomplete list that does not contain France and Germany. Yet it is pointed out that 'authorities usually negotiate a contract for several years' and pay a lower price than domestic households and sometimes less than industrial consumers (Van Tichelen et al., 2007-01, p. 87).

[238] Gas-discharge lamps or LED lighting does not switch off at once, as incandescent light bulbs do. Instead, their light flux decreases over time. The phenomenon is also referred to as degradation. In light planning and also in the EU performance standard, the so-called maintenance factor (MF) accounts for this degradation.

each other than the Berlin lights. Regarding the light sources and output, gas luminaires are famous for emitting a warm but also dim light. Finally, the age difference of the installed equipment suggests that comparable lighting technologies perform differently in the two cities. While Lyon is constantly modernising its lighting equipment,[239] Berlin struggles with an investment backlog. In 2007, the Senate reported to the Berlin Parliament that 'substantial parts of the lighting equipment have outrun their economic lifetime and must be considered outdated' (Abgeordnetenhaus Berlin, 2007-09-13, p. 2).

But there is another reason for Berlin's darkness, namely a political decision. In the late 1990s, the light levels were reduced by half when the untranslatable so-called *Halbnachtschaltung* became the norm. In electric luminaires with two light tubes, one of them was switched off permanently (NSR, 2012-07-03).[240] The reduced public lighting scheme saved the city energy costs but was also consequential in other respects. Ten years later, when the Senate and the Parliament considered a reintroduction of the old illumination scheme, they concluded that the cost of modernising the light control system was too high (Abgeordnetenhaus Berlin, 2007-09-13, p. 4). Twenty years later, the downsizing also affected the introduction of LED lighting in Berlin. As outlined above (4.3.1), the BMU granted financial support for infrastructural refurbishments only if the energy consumption could be reduced by at least 60 per cent. In Berlin, the reduced light levels made it quite impossible to achieve the required energy reductions and the Senate Administration did not apply (SenStadtUm engineer & lighting engineer, 2012-12-11).

In Lyon, a permanent reduction of light levels seems less of an option and the municipal light planners explore a different approach to reduce their energy consumption. According to their climate change mitigation strategy, the city aims to reduce its energy consumption for public lighting to one-fourth of the 1990 value. This objective has become even more important in the face of rising energy prices. The sudden 'brutal' price increases of more than 20 per cent in one year incentivise energy efficient solutions (Ville de Lyon, 2011, p. 8).[241] But the Lyon lighting equipment is not as outdated and inefficient as the Berlin gaslights. The municipal

[239] In 2004, the average age of Lyon's public light installation was less than 14 years (DEP, 2004). In 2011, one third of the light points were less than ten years old and 25.5 per cent more than 25 years old (Ville de Lyon, 2011, p. 8).
[240] '*Halbnachtschaltung'* means that at a certain hour, usually late at night when traffic is low and streets are empty, the light levels are reduced via a remote signal. The two-phase lighting scheme was suspended in 1996. Ten years later, the Senate considered its reactivation but refrained from the plan due to high modernisation costs (Abgeordnetenhaus Berlin, 2007-09-13).
[241] A civil engineer told me in Septembre 2013 that since January 2012 prices have increased by 30 per cent (NSR, 2013-09-19).

light experts figure that they cannot achieve their ambitious goal just by installing more efficient luminaires without reducing the light levels below their standards. Therefore, they reconsider and modify the daily operating times of the public lights. The term '*temporalité*' stands for a new approach and critical reflection on 'lighting where and when needed'. A municipal engineer explained the approach as follows:

> 'With the principle of temporality, we said, on nights, weekdays, during the month, the year, the users, inhabitants, tourists, don't have the same needs. They have safety needs when they come home from work, on weekends they have more festive needs, in summer and winter the sun doesn't set at the same time. They don't have…it's not the same temperature outside. You're more inclined to go for a walk when it's 25°C than when it's 10 below. So the idea was to adapt lighting to the needs of the population, and naturally that reinforced this relationship and need for communication between the city government and the population, because if we want to adapt lighting to meet needs, the first thing we need to do is to define those needs' (DEP lighting engineer, 2012-01-06).[242]

This temporal approach can be considered a complement to spatially organised modernisation activities. It also draws attention to larger technical systems which are described as follows.

5.2.2 Larger technological infrastructures: Power and control

As we have seen, existing lighting infrastructures are closely linked to electricity networks. One century ago, the introduction of electric light bulbs depended on the establishment of these 'large technological systems' (Thomas P. Hughes, 1987).[243] Today, electricity grids build the basis for the establishment of more or less radical LED lighting systems. The same applies to the larger technological infrastructures that are in place for remote-controlled public lights, that is, to switch them on and off every day. In both respects, adaptations are necessary.

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242 OV : *« …avec le principe de temporalité, on a dit dans la nuit, dans la semaine, dans le mois, dans l'année les usagers, les riverains, les touristes n'ont pas les mêmes besoins. Ils ont des besoins sécurité pour rentrer du travail, le weekend ils ont des besoins plus festifs, en été et en hiver la nuit tombe pas la même heure. Ils ont pas… il y a pas la même température dehors. On va plus facilement balader quand il fait 20 dégrée dehors plutôt quand il fait moins dix. Donc, l'idée était d'adapter l'éclairage aux besoins de la population. Et forcement ça renforçait ce lien et ce besoin d'échange entre la collectivité et la population. Puisque, si on veut adapter l'éclairage au besoin la première chose c'est définir ces besoins »* (DEP lighting engineer, 2012-01-06). The approach is also scientifically explored by Jean-Michel Deleuil (Schulte-Römer, 2010).

243 Vice versa, the emergence of electricity networks is closely linked to the global victory of the electric light bulb over gaslights. The powerful image of clean electric lighting helped Thomas A. Edison build and promote his famous networks of power (Bazerman, 1999; Thomas P. Hughes, 1983).

In the 21st century, electricity infrastructures are standardised. In Europe, public and private electricity utilities supply an electric alternate current (AC) at a voltage of roughly 230 V (±10 %). As LEDs are supplied with low-voltage direct current, manufacturers produce luminaires with built-in ballasts and drivers which convert the standardised high-voltage electric current into the specific electric current needed. In theory, LED luminaires are thus connectable and compatible with existing urban infrastructures. In practice however, connecting LED luminaires to existing energy grids can be much messier than that. As we will see in chapter 6, the installation of LED lighting is affected by local particularities in the supply infrastructures.[244] Electric grids thereby differ not only across cities but can also vary *within* cities, as the Berlin case shows.

The West Berlin gaslights are not the only relicts of the city's division. The electric grids for public lighting, too, have developed differently in East and West. In the western part of the city, luminaires are directly connected to the grid while in East Berlin lights are often linked in so-called ring connections. That means that the public lights in these streets have separate electricity grids which are linked to the general electricity network via one power distribution box per grid. All these grids are operated by a private energy supplier, while the light points are managed by a subsidiary of this company (5.4.2).

In Lyon, electricity is provided by the French national energy company. The energy supplier also operates the municipal electricity grid. But the Lyon public lighting service operates its own electricity grid for public lighting which is, like in East Berlin, separated from the general grid for domestic, public and commercial energy supplies. According to a Lyon civil engineer, the Lyon public lighting service prefers this extra grid as it allows them to maintain and manage their system more autonomously and, as they say, also more cheaply (NSR, 2011-11-29a, 2013-09-19). Instead of having to cut open big earth cables they have quicker and easier access to the cables that feed public lights. The cables are also much smaller and can lie above-ground.

In contrast, Berlin electricians and engineers prefer the direct connection arguing that 'the whole street goes dark' if one component of the ring connection fails (NSR, 2012-07-16).[245] After reunification, it has become customary to connect power lines and lamps one by one.

[244] Already the historian Thomas Hughes has famously shown (1983) that 'networks of power' evolved in context-specific ways in Berlin, London and Chicago.
[245] In Marseille, they have developed a system that reconnects light points via an alternative line in the case of failure. (NSR, 2013-09-18/19/20/21)

The ring-connection system will eventually disappear (NSR, 2012-07-16). On the downside, there is no way round expensive underground works whenever new light points are connected in Berlin. In July 2012, I witnessed how gaslights were replaced with LED lanterns in Saalestraße in the district of Neukölln. The following field notes document the work involved in connecting LED luminaires to the local larger technical system.

Field notes: Saale Street under construction, four days in July (excerpt NSR 2012-07-16)

I return on Wednesday (2012-07-18) at 8:30am, which turns out to be a perfect moment. Peter and Micha, who work for one of the [light managers'] subcontractors, are about to begin their work. The previous day they have connected five luminaires. Every lamp post is connected to the electricity grid with the advantage that in the event of a failure, only one lamp will be affected so that larger blackouts, e.g., in a whole street, can be avoided.

Peter starts heating the rubber protection around the central electric power line, the earth cable. He explains there are three 220V wires, i.e., a three-phase alternating current (AC), inside the earth cable adding up to 11 kilo Ampère. When he gets to the aluminium mantle he rolls out a rubber mat for local insulation (*Standortisolierung*). While he is cutting open the cable he stands in an approximately 2 to 3 meter deep earth hole, under an umbrella that protects him from the rain. Micha calls it a 'perfect hole' ("*Bilderbuch Grube*"). He cannot always work under such 'perfect' conditions. Cavities are sometimes not much bigger than the cable junction box, he says, because building requirements do not permit larger holes (e.g., regulations for public spaces require that baby carriages can still pass on the sidewalk during street construction work).

They tell me that underground works used to be less expensive than the work of electricians. But this has changed now. I imagine the machinery is expensive and the excavation difficult and even risky. It is not at all obvious what kind of cables and pipes are buried in the ground as the cables stem from different epochs and plans are not always complete (NSR 2012-06-25) or non-existent (NSR 25/01/12).

Peter is now working on the aluminium mantel and the oil-soaked paper that keeps the electrical resistance low. Meanwhile, Micha is connecting a cable to the distribution box inside the lamp post. I ask if there is a difference in installing LEDs compared to other jobs. None, he says. […] Peter tells me that only two of the three phases of the cable are connected to the post. The light manager would like to have them all running to the distribution box but the luminaire cases do not allow for connecting the wires safely—a compatibility issue.

After he has connected the cables to the lamp post Micha moves on to the next pole. Peter installs the cable joint, which is a round disc with little knives inside that can cut through the oil soaked papers until the joint touches the electrical wires of the earth cable. The cable joint sits in a large plastic cable junction box. The cables that lead to the luminaire are threaded into the box. After the disc is applied and the luminaire connection is properly attached, Peter starts closing the box: First, he closes its openings on both sides with a white foamy material. He then attaches the lid to it and rubs sand into the openings. When I ask why, the electrician explains: 'we are not working under laboratory conditions here.' In the lab, the materials work fine, but here on site the foam might not be good enough to keep the hole sealed.

To make sure that no water will enter, the cable joint box is finally filled with cleansed tar. Once the heated liquid tar has cooled down the box is sealed.

Figure 5-6: Electrician working on the Berlin electricity grid (CC).

Electricity grids can also fulfil a second function in public lighting, namely provide the infrastructure for remote-controlled lighting according to the daytime and season. In this case, the signal that switches the light points on and off is an amplituninal change in the electrical current. This so-called ripple control system *(Tonfrequenzsteuerung)* is used in Lyon. In Berlin, the lights used to be controlled by ripple control, but after reunification, the Senate Administration changed to a different technology, namely the so-called European radio ripple control system (EFR—*Europäische Funk-Rundsteuerung*). Since 1997, the impulse that switches the Berlin light points on and off is a long-wave radio signal, which is sent from an EFR station near Magdeburg.[246]

The system change is a side effect of the privatisation of the Berlin electricity utility Bewag. The Senate decided to install EFR receivers when the private energy servicing company raised the operating fee for the ripple control system by more than 100 per cent and announced that it would end the service altogether in 2008 (Abgeordnetenhaus Berlin, 2005-10-19, p. 5). All new installations are now equipped with radio signal receivers and thus connected to the new standard system. As we will see (6.2.1), the recent investment can be used as an argument against the introduction of intelligent LED lighting systems.

A third technology is still used in East Berlin, where some luminaires are still equipped and switched on and off by daylight sensors. As an electrician pointed out, they are quite susceptible to failure—a shadow or bird droppings are enough to make luminaires run all day (NSR, 2012-07-16).

To conclude, these larger technological systems can be considered matters of fact as long as they work, but can turn into matters of concern in the course of LED installation processes (cf. Latour, 2004). As we will see in chapter 6, their obduracy or the interests of their operators can lead to complications when innovating in public.

5.3 Light planning: Innovative approaches and urban visions

Light plans are a policy tool for harmonising lighting practices and objectives on an urban scale. They affect public lighting infrastructures by outlining modernisation or urban regeneration strategies, by stimulating or steering demand and by offering guidelines for the public procurement of new lighting equipment. Therefore, I consider light planning as a reflexive practice that can change and visibilise obdurate urban infrastructures.

The City of Lyon was considered as a pioneer presenting a light plan in 1989. Since then, urban light planning seems to have reached a new level of institutionalisation (4.3.3). In a

[246] See: http://www.efr.de/efr-system/, 2014-08-02.

qualitative survey[247] we found that half of the 44 largest German cities have developed light plans and strategies in the past decade with a significant rise between 2005 and 2010. Yet, we also found that these municipal light plans can hardly be compared as they vary with regard to the experts and municipal departments involved in the planning, with regard to their objectives and implementation strategies.[248] This also applies to the light plans of Berlin and Lyon.

5.3.1 The Lyon 'Plans Lumière'

The Lyon light planning activities can be understood as 'a more global economic development strategy with urban regeneration as its 'spearhead' and a means to support the regional lighting industry (Gonzalez, 2010, pp. 79, my translation). Three favourable factors enabled this policy innovation. First, Lyon had an image deficit (black city) but a strong economy (rich city) and an attractive urban landscape (hills, rivers, historic buildings). Second, the city already had a traditional affinity to the subject of light and hence cultural assets that could be mobilised (the ancient name Lugdunum, Fête des Lumières, the cineaste brothers Lumière). Third, the new policy was built on an already existing local 'pool of innovative actors' and supported a number of small and medium-sized enterprises in the sector (cf. Gonzalez, 2010, pp. 18, Marescaux 2010). Decorative lighting schemes had already been put in place with positive resonance by commercial actors in a shopping street. The municipal public lighting service had also already started to illuminate Lyon landmarks.[249]

The first Lyon *Plan Lumière* is generally referred to as the first of its kind and perceived as a starting point of nocturnal urbanism (4.3.3).[250] In 2004, the first Lyon light plan was superseded by the New Light Plan (*Le Nouveau Plan Lumière*), which set new objectives and

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[247] The survey on urban light planning practices was conducted in 2010 by Robert Wagner during his internship at the WZB. The survey is based on telephone interviews with municipal actors from the civil engineering and urban planning departments of all German cities with a population of over 200,000.

[248] This observation was confirmed by a quantitative survey by the urban light planner Dennis Köhler and his transdisciplinary team at the Polytechnic Dortmund (http://www.fh-dortmund.de/de/fb/1/forschung/Licht.php). The survey showed that 500 cities and communes in Germany have developed some sort of strategies or measures in the urban lighting field (2012). Köhler further suggests that municipal light plans are designed in order to ‚aestheticise uncanny urban spaces on the basis of politically legitimised financing'. He criticizes that such nocturnal urban planning programs tend to produce single illuminated objects rather than coherent frameworks.

[249] According to the former head of the Lyon public lighting department, the light plan was only a logical continuation of their public lighting practice (NSR, 2011-12-09b).

[250] In his doctoral thesis, the urban planner Edna Hernandez Gonzalez (2010) uses Lyon as a model case and studies 'the modalities of reception and appropriation' of its innovative urban strategy in the Mexican cities Puebla, Morelia and San Luis Potosi. Gonzalez portrays the City of Lyon as an reinventor of urban lighting, making it 'a primordial vector of urban policy (Gonzalez, 2010, pp. 74, my translation).

expanded Lyon's light planning strategy into the wider urban community. In 2010, the city's lighting strategy was revised in the course of the EU-funded PLUS project, [251] a programme for expert exchange on best practice and sustainable public lighting. Each of these stages corresponded with new objectives and further-developed approaches.

With its first *Plan Lumière*, Lyon implemented an aestheticised lighting strategy, which had been developed by a trans-disciplinary team of municipal lighting engineers, urban designers, and politicians. In 1989, the light plan presented an innovative complement to the then still prevailing planning paradigm of the car-friendly city, commonly referred to as 'functional lighting'. Embellishment activities came first. The first light plan focused on the more central districts of the city and promoted a city image that could be mediatised and exported; an image that all Lyonnais could 'be proud of'. The illuminations were reinforced by further reaching regeneration activities that aimed at improving the quality of public spaces also during the daytime. For instance, the light plan accompanied a 'colour plan' which incentivised house owners to paint their houses in line with a specific colour code—white and blue along the Rhône River and rose along the Saône. A key promoter of the light plan points to the reciprocal effect of the regeneration programs: 'It is by playing on the coloured facades, the recreated decors and well-chosen materials that the light creates a new magic (Chabert, Monnami, Jaillard, & Durdilly, 1999, p. 29).[252] The ambition of Lyon's city fathers to promote their city's image by illuminating thus became manifest and publically visible in the streets. In the course of the 1990s, 267 sites were *mis en valeur*, that is, developed by means of illumination.[253] Among these sites were public buildings, art works, cultural heritage sites, architectural objects and natural sites on the hills or river banks. The approach was pragmatic rather than analytic, a key actor called it 'arbitrary' as it depended on the capacity of public services and the actors' 'feeling' (Gonzalez, 2010, pp. 81-82). Yet the Lyon light planning was gradually institutionalised.

The first light plan drew public and media attention to Lyon's lights. But it also strengthened and expanded the local urban lighting network as it was built on the collaboration and financial support of the local electrical industry, more precisely the local energy utility, and

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[251] For more information on PLUS (*Public Lighting Strategies for Sustainable Urban Spaces*) see: http://www.luciassociation.org/more-about-plus.html, last access 2014-07-31.

[252] Underground parking lots were painted and turned into art works. « Cette mise en beauté urbain était un préambule indispensable au Plan. Car à jouer sur des façades colorées, des décors recréés, des matériaux bien choisis, la lumière apporte une féerie nouvelle » (Chabert et al., 1999, p. 29).

[253] The first 14 projects were already realized in 1989, 12 in 1990, 24 in 1991, 43 in 1992 and so on. (Gonzalez, 2010, p. 80).

local distributors and manufacturers of electrical and light equipment (Gonzalez, 2010; Marescaux, 2002).[254] In turn, the private collaborators profited from the positive public appeal of the outcome. Furthermore, the lighting network was also expanded as new actors were invited to participate in public lighting, namely Lyon lighting designers *(concepteurs lumière)* or light planners *(éclairagistes)*.[255] Today, there are a number of Lyon-based lighting designers. The city also became a showcase for the diversification of urban lighting design approaches.[256] The embellishment policy was reinforced by the above-described extension and promotion of the Fête des Lumières (5.1.3), which created a scene for lighting design in all its variety, including festive ephemeral and perennial decorative schemes.

The first light plan gradually changed the objects and objectives for public lighting in Lyon. While road safety and security had been the key arguments before, the new approach emphasised and explored the gain of public lighting in terms of local identity, cultural heritage and also revenue of the city's night-time economy. This also had an impact on the installation of lighting technology, including LEDs, as it increased the demand for decorative and architectural lighting.

In 2004, the City of Lyon presented its *Nouveau Plan Lumière.* The update of the lighting strategy underlined the city's political will to stay ahead of things and took public lighting in Lyon to a next level by means of critical and trans-disciplinary reflection. The new strategy was developed in the course of three workshops. A Lyon light planner explained:

> 'The goal of the first plan was to showcase the city... a cultural approach. The second was to bring light into the heart of the neighbourhood, as close as possible to the population, and notably its habits' (DEP lighting engineer, 2012-01-06).[257]

The integrated trans-disciplinary approach 'implied profound changes in the professional cultures' (Gonzalez, 2010, p. 105). For instance, instead of involving light planners in the last stages of building or regeneration projects, they should now be involved in the early stages of

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[254] Gonzalez points out that the private contributors also had a vital interest in the success and diffusion of the Lyon lighting policy (2010, p. 85).

[255] French *éclairagistes* just like *Lichtplaner* in Germany like to stress that they are not conceptual artists but know the art of lighting, that is, the techniques, technologies and science of lighting and creating light effects.

[256] Lyon also became a showcase for the diversification of urban lighting design approaches. Within the following years, 'façadic' architectural lighting was complemented by vertical designs for urban spaces (Marescaux, 2002, p. 29).

[257] OV*: « L'objective c'a été du premier de mettre en valeur la ville, une approche patrimoniale. Le deuxième, il est plus de ramener la lumière au cœur des quartiers au plus proche de la population »* (DEP lighting engineer, 2012-01-06).

a planning process. The workshops were also institutionalised. Light planners and urban designers from the City of Lyon or Grand Lyon meet regularly to discuss and align their work and urban design approaches (Lyon, 2010, p. 9; NSR, 2012-01-23).

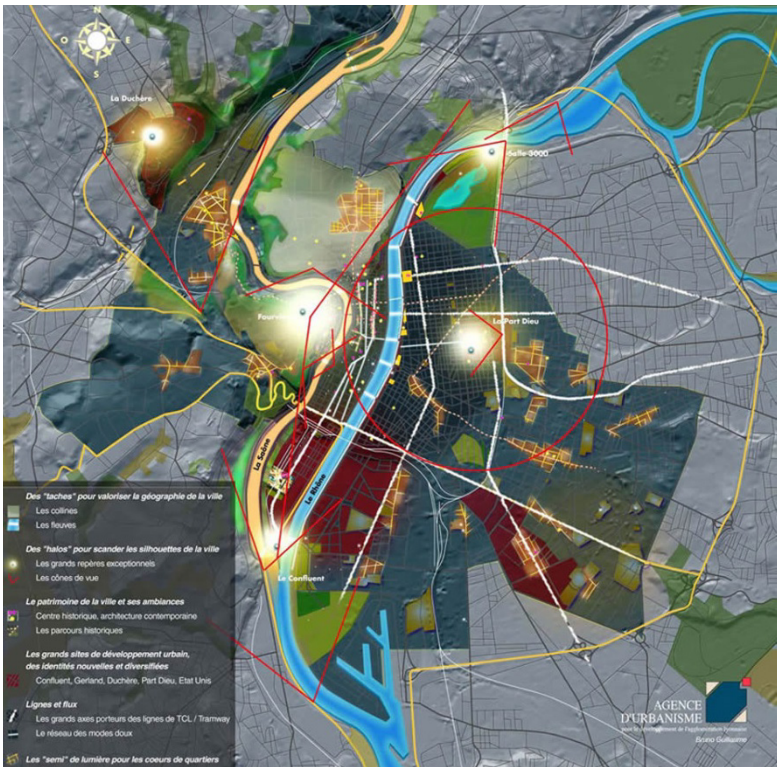

Figure 5-7: The *Nouveau Plan Lumière*—light planning beyond the city centre (CC).

The new strategy is also designed to strengthen public participation. In the internal workshop documentation it was stated that the first plan evoked the spectacle in the street, leaving the private individual passive like 'in front of the TV'.[258] The new light plan aims to decentralise public light planning. 'L'humanisme' is highlighted as a key objective, rather than 'l'image' (Ville de Lyon, 2004, p. 29). In this context, temporary light installations like Fête des Lumières projects are considered as a 'barometer' for public consent (Gonzalez, 2010, p. 106). Sustainability issues are another new objective.

The 2004 sustainability strategy includes the progressive modernisation of existing lighting equipment and the testing and implementation of 'green' sources. Additional quality criteria for new installations are good colour rendering and warm-white colour temperatures (3,500

[258] This criticism resonates with Guy Debord's more general criticism of the 'Society of Spectacle' (1967)..

Kelvin) (Ville de Lyon, 2004, p. 15). The new light plan also entails the commitment to recycle lamps and to phase-out poisonous light sources, like mercury vapour lamps or components that contain lead. Further issues raised were the reduction of light pollution and the introduction of a new light operating system in order to simultaneously improve failure detection and reduce the cost and energy consumption (Ville de Lyon, 2004, p. 16).

The procedural, open approach and the heterogeneity of objectives of practice are reflected in the notion of *experimentation*. Temporal site-specific interventions are considered as tests for perennial installations. Street-level testing of reduced light levels, temporal programming of public lights or presence control is described as a means to explore new lighting techniques and adequate responses to environmental and urban challenges (Ville de Lyon, 2004, p. 27).[259] Experimenting is thus established as a means to stay ahead of things.

Accordingly, the *Nouveau Plan Lumière* also accounts for recent technological developments. In 2004, LED lighting is described as a 'supplementary technology' with a high energy-saving potential and the option to control lighting dynamically—but not yet as an alternative to existing street lighting technology like high-intensity discharge lamps (Ville de Lyon, 2004, p. 18). Since then, LED technology has become more performant. Dimmable and controllable as it is it matches well with Lyon's sustainability strategy and commitment to illuminate only '*where and when needed' (« là et quand c'est necessaire. »)* (Lyon, 2010, p. 15).

In 2010, the Lyon lighting strategy was again under revision when the City of Lyon joined the EU INTERREG project *Public Lighting Strategies for Sustainable Urban Spaces* (PLUS). The program aimed at improving urban lighting policies and promoting energy-efficient lighting solutions. In the course of the project, Lyon and ten other European cities presented and discussed their public lighting practices and approaches in a series of meetings and workshops. With so-called 'deep dives', external experts scrutinised and evaluated the cities' sustainability strategies and gave recommendations (cf. GOJA, 2011).

This time, LED technology was at the centre of attention, as 'a solution for energy efficient public lighting strategies' (LUCI, 2012a). The project partners concluded the LED technology indeed offered solutions to contemporary challenges, including CO_2 reduction, cost and

[259] OV : *« Lyon en taut cas devrait se donner les moyens de l'expérimentation pour décider de ce que l'on peut enlever ou réduire. L'autre solution intéressante du point de vue écoloqique serait les détecteurs de mouvements. Sécurité et éclairage individuel seraient ainsi compatibles. »* (Ville de Lyon, 2004, p. 33).

energy efficient lighting and light pollution 'but not on all levels and not for all contexts.' The representative of the lead partner Eindhoven is quoted as follows:

> 'With their high energy efficiency, longer life span and increased flexibility, LEDs are often proclaimed as the urban lighting solution of the future. However, through our Deep Dive analysis of the cities that have implemented this technology, project lighting experts have come to the conclusion that while LEDs are appropriate in particular contexts for some cities, the high investment costs involved and the rapid technological evolution means that they might not be the best answer for all cities at the moment' (LUCI, 2012a).

The project partners presented their insights and experiences in project reports (LUCI, 2012b), a number of conferences and public events[260] and were featured in the EC's green paper on SSL (European Commission, 2013-06).

By participating in the PLUS programme, the City of Lyon thus restated its commitment to economically, environmentally and socially sustainable lighting in public. But it also underlined its interest in professional exchange within an international urban expert community. This extension of the Lyon public lighting network will be further outlined below (5.4.1) but first I will turn to the Berlin light planning strategy titled 'city image Berlin'.

5.3.2 The 'Stadtbild Berlin' lighting strategy

In Berlin, the starting situation that led to the development of an integrated lighting strategy was dominated by the need to modernise and harmonise the city's outdated infrastructures. Other than in Lyon, the illumination of monuments, beacon buildings and other 'places of particular light relevance' *(Orte besonderer Lichtbedeutung)* is only one objective among others, such as energy efficiency, ecological considerations and security in public spaces (SenStadtUm, 2011). Most importantly, the light plan contains a *technical implementation rule*, the *Ausführungsvorschrift Öffentliche Beleuchtung* (AV ÖB) that outlines local quality criteria for light planners and regulates the planning process in order to facilitate the coordination between all public and private partners, including the districts.

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[260] For a documentation see: http://www.luciassociation.org/presentations-eusew-led-lighting-strategies-for-urban-spaces.html, last access 2014-07-31.

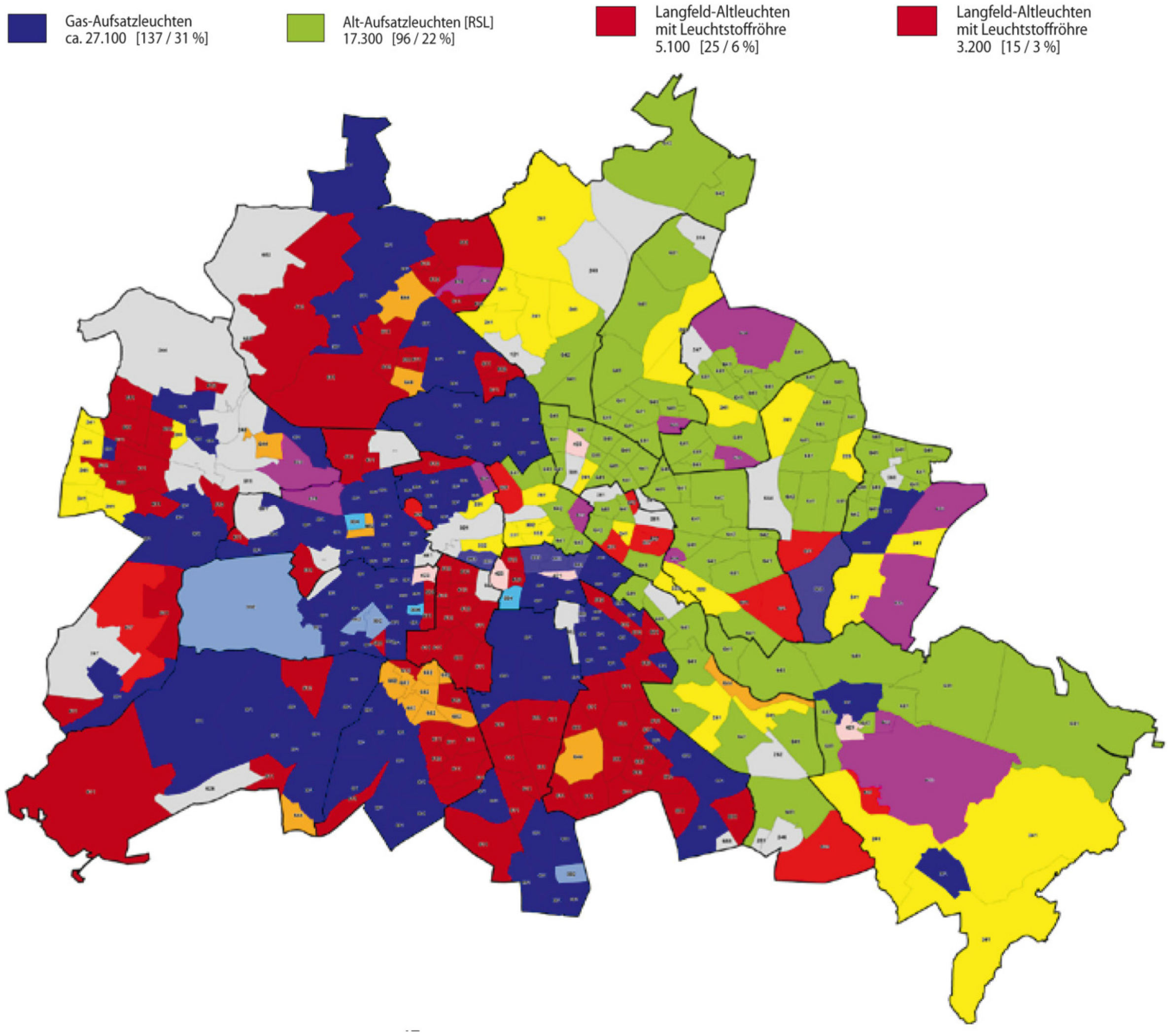

Figure 5-8: Berlin map of the four most common luminaire types (SenStadtUm, 2011, p. 47).

The light plan succeeds a less comprehensible public lighting strategy which focused on the modernisation of the Berlin public lighting infrastructure (Abgeordnetenhaus Berlin, 2007-09-13). The initiator of the light plan was not the civil engineering department but the urban design unit within the Berlin Senate Administration. A key motivation was the harmonisation of luminaires and urban design and to reduce the diversity of different luminaire designs (SenStadtUm urban designer, 2010-02-22).[261]

[261] The urban designer who was the driving force behind the light planning had tried to initiate the processes earlier already but her ideas were rejected by her superior. But when a new Senate Director for urban development (*Stadtbaudirektorin*) started her work in 2007, city lights became part of the urban development agenda (SenStadtUm urban designer, 2010-02-22). The new director could also draw on experiences with light planning from her previous position in Zurich (NSR, 2011-04). It was also a good moment for the administrative organisation. In August 2006, the responsibility for public lighting had been given back from the district level to SenStadtUm (cf. Abgeordnetenhaus Berlin, 2006-02-07).

There are luminaire designs from the 19th, 20th and 21st centuries and more than 200 luminaire types in more than a thousand different technical variants.[262] The great variety also makes it difficult to operate and maintain Berlin's light points efficiently (SenStadtUm, 2011). Refurbishments cannot be carried out as collective orders. Repair services need to be prepared to replace non-standard components in a luminaire or increase the variety even more by improvising with the spare parts available at hand.[263]

The municipal urban designers had to develop a guideline for light planners accordingly. It tells them not only which light distribution and pole distance is recommendable for which type of street, as the EN 13201 does it, but outlines in all technical detail which luminaire types and designs are eligible for which architectonical ensemble (or LOR, see 5.1.1). As numerous area plans and illustrative photos show,, street luminaires in modern socialist building blocks from the 1950s should differ from those of in 19th century urban quarters *(Gründerzeit)* or village-like areas, which can also still be found in Berlin.

As in Lyon, the Berlin lighting strategy was developed by an expert panel in transdisciplinary discussions. The working group's meetings, hearings and site visits finally resulted in the Berlin light plan that goes beyond efficiency criteria and functions as a planning and procurement framework (SenStadtUm, 2011).

In the course of the expert consultation, lighting designers advised the municipal planners on how to develop quality criteria for public lighting in Berlin. The guidelines should also account for the look and feel of public spaces and human well-being—not only traffic safety– and be less complicated than the EN 13201 (see 4.3.2). A sociologist was invited to critically evaluate the correlation between light and traffic accidents during the dark hours of the day (in December this means between 4pm and 8am). The study showed that there is no significant correlation between the number of accidents and the measured brightness of Berlin streets (illuminance in lux). 19 per cent of Berlin accidents take place after dark. Pedestrians are over-proportionally often badly injured or killed (NSR, 2011-04). Thus, the illumination of pedestrian crossings received special attention in the lighting strategy (SenStadtUm, 2011).

Furthermore, the expert panel took into account the impact of light spills on the urban eco systems in Berlin's important green areas and parks, lakes and rivers. In this context, LED

[262] The 2007 lighting strategy mentions 'approximately 1,600 different luminaire types and technical variants' (Abgeordnetenhaus Berlin, 2007-10-11).
[263] In contrast to Lyon, Berlin does not store spare parts.

technology was explicitly mentioned as a promising option since diodes without UV components are, together with low-pressure sodium lamps, considered an insect-friendly light source (SenStadtUm, 2011).

Compared to the Lyon light plans, the public appeal of the Berlin light plan seemed less important. The strategy brochure, and especially the AV ÖB, offer experts a guideline for their professional practice with the goal to improve public lighting practice and urban infrastructures. The title of the brochure 'City Image Berlin' ('*Stadtbild Berlin')* evokes the notion of grand vistas and urban landmarks but, in fact, the light plan seems more concerned with the immersed experience and coherence of urban ensembles.[264] Against this backdrop, the necessary modernisation of the outdated lighting infrastructures in East and West Berlin offered not only a chance to reduce the public energy bill and maintenance costs.[265] It was also an opportunity to reduce the extreme aesthetic variety of Berlin's lighting equipment. Thus, the light plan preserves the urban fabric and underlines the existing city image rather than transforming it as was the case in Lyon.

Another difference concerns the transdisciplinary collaboration. While the light planning *processes* appear to have been quite harmonious in both cities,[266] the Berlin light plan caused a controversy over evaluative methods when it was presented in public. During the event in Berlin in 2011, the Senate Director for Urban Development explained that Berlin was dark and should remain dark as the planning team considered the low light levels as appropriate (NSR, 2011-04). The event was mostly attended by municipal actors and lighting professionals. In a subsequent heated debate, lighting engineers objected and heavily criticised the implementation regulation. The AV ÖB is not in line with technical standards for good lighting as they are outlined in the DIN EN 13201 (NSR, 2011-04, 2012-09-12/13/14). Instead, it highlights the planning team's principle of 'appropriateness'. They claim that their recommendations are still within the lower limits of the DIN-EN 13201 and much easier to apply because the AV ÖB requires less sophisticated photometric measurements than the European standard.

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[264] This corresponds with the 'humanist' approach of the new Lyon light plan as outlined above. Michel de Certeau describes and contrasts the distanced panoramic perspective and the immersed way of experiencing urban spaces and cities (1984).

[265] The light plan repeats the Senate's commitment to electrify the Berlin public lights, as it was already decided upon in 2007 (Abgeordnetenhaus Berlin, 2007-09-13).

[266] As my colleague Katharina Krause reported after an interview, the key urban designer claimed that ‚no conflicts arose' in the elaboration phase (Krause & Toschka, 2013-02-14). The same is claimed for Lyon (Gonzalez, 2010).

Thus, the debate was essentially a conflict over how to evaluate and determine appropriateness: While the lighting engineers rely on laboratory experiments and photometric tests, the Berlin expert panel developed their quality standards on the basis of real-world evaluations. Categories had been developed in the course of site visits under the guidance of a lighting designer. From a lighting engineering perspective, this method appears inadequate as it takes urban situations as a yardstick and privileges an expert group's sense of appropriateness and simplified photometric values over scientific state-of-the-art performance criteria and standardised measurement procedures.

Yet there is another conflictual point: The quality criteria of the Berlin light plan also contradict the modernisation plan of the private light manager. This modernisation strategy is an important part of the management contract.[267] The contracting model incentivises the private manager to rapidly render Berlin's lights more efficient:[268] Within the first two years of the contract, the money saved via energy savings is credited in full to the manager. Later, the city will have its share (SenStadtUm civil engineers, 2012-12-05). Yet the modernisation strategy is incompatible with the municipal light plan, which became effective before the new manager started its work.[269] The light plan requires that Berlin's public spaces are in 'warm-white' light or more specifically, in colour temperatures between 2,700 and 3,200 Kelvin (SenStadtUm, 2011). The light manager proposed to dismantle single light points in well-lit streets and to replace inefficient white light sources with energy-efficient *yellowish* sodium high pressure lamps. The head of the public lighting unit characterises this strategy as 'minimal effort' with huge effects in terms of cost and energy saving. But they also said 'we'll never do it' (SenStadtUm civil engineers, 2012-12-05). A Berlin light professional argued that the light plan has 'diluted' the management contract (NSR & Toschka, 2013-05-29).

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[267] When the invitation to tenders was published in December 2008, the Senate explicitly asked the bidders for a modernisation strategy from which they should also benefit financially through the contracting model. The current light managing firm won the tender with an unbeatably low management fee and an inacceptable modernisation plan. According to a rival bidder, the feasibility of the proposal only played a subordinate role in the evaluation of the tender: The bidders' management prices were weighted 80 per cent, the modernisation plans only 10 per cent. Thus, the bidder with the cheapest management fee won the contract despite its 'worthless' modernisation strategy (NSR & Toschka, 2013-05-29).

[268] The contract contains a number of incentives designed to encourage energy savings. An energy saving coefficient, which was also part of the tender, indicates how much energy per invested Euro the manager claims to save. The current manager's bid was 0,3 Watt per Euro. The bonus for modernisation measurements is also linked to this bold claim (SenStadtUm civil engineers, 2012-12-05).

[269] The Berlin light plan was developed during an ongoing legal conflict between the bidders over the management contract. None of the rival light managing firms had been invited to participate in the development of the light plan (NSR & Toschka, 2013-05-29).

Indeed, the compatibility issue is delaying the modernisation process which is costly for both the city and the manager. The private manager has already indicated that they will claim compensation for not being able to carry out the planned modernisation works and for not receiving the bonus (head light manager; 2013-06-10).

We can conclude that the light plans of Lyon and Berlin present city-specific frameworks that also affect the choice of new technologies. In both cases, they require that public lighting should not only be efficient but also warm-white. The light plans raise issues like light pollution—a point that is more elaborated in Berlin—and a 'humanist' approach. While the Lyon light plan explicitly promotes experimental public lighting practice, the Berlin light plan is rather prescriptive and outlines planning procedures and criteria. To be specific,, the Lyon light planning seems more process-oriented while the Berlin lighting strategy is more result-oriented.

As we will see, there is much more to be said about light plans and their effects on innovation. In particular, they facilitate and institutionalise an exchange across municipal departments and between public and private actors from different professional backgrounds. For instance, in Lyon, the municipal actors and their consultants who developed the first light plan strongly identify with the process and proudly present their achievements. The director of the Lyon public lighting department, who was part of the team that developed the first Lyon light plan, seems to have very positive memories of the process. 'That was the family', he said with a smile when he showed me a group photo of the team (NSR, 2012-01-31).[270] In Berlin in contrast, it seems that the public lighting and urban planning units within the Senate Administration have not yet grown together. 'We are not best friends', remarked one of the actors diplomatically. In fact, this does not seem surprising, when we take into account the tense situation in the Berlin Senate Administration which brings us to the urban public lighting networks, which are the subject of the last section of this chapter.

5.4 The Lyon public lighting service and the Berlin public-private partnership

Public lighting services involve both public and private actors, who collaboratively perform the tasks and routines of lighting cities. Public-private relations and partnerships can differ

[270] The light plan was indeed a collaborative success. It is impossible to make out one key actor or spokesperson (Marescaux, 2002)—even if some claim they initiated the process.

significantly across cities—and even more so when comparing cities to smaller towns or communes. The key roles in public lighting relate to different stages in the lifetime of an installation, from its conception to its replacement, and can be described as follows.

First, *the development (Bauherrenschaft/maîtrise d'ouvrage)* lies in the hands of the municipality. Political representatives have the last word. The developers' role is distributed: Political actors allocate funds, municipal public procurement units publish tenders and civil engineering departments offer them the information, including technical product specifications and arguments for justifying projects in public. In my study, I only focused on the civil engineering departments. The *construction management (Bauleitung/maîtrise d'ouvrage)* includes the planning and supervision of installation processes on site. In most cities, the management is outsourced to private firms. Construction managers also commission installers in coordination with the developer. Finally, public lighting installations are run and maintained by a public or private *operator (Betreiber/exécutant)* that ensures that lights are up and running, or commissions contractors to do so. The operator also plans and carries out standard modernisation procedures like lamp replacements and repair jobs.

Although the basic roles and responsibilities are quite the same in contemporary cities, public lighting services show a variety of different organisational and contracting models. Again, Berlin and Lyon are extreme opposites. While in Lyon, the municipal lighting department is actively involved in all steps from development to maintenance, the provision of public lighting in Berlin is highly distributed, evenly dispersed across municipal and private organisations, and appears under construction. As we will see in this section, the two services also differ considerably with regard to how they share responsibilities and build relations with private installers, system operators, political decision makers and colleagues from other departments or other cities. The municipal organisations in charge of street lighting in Lyon and Berlin are the *direction de l'éclairage public* (DEP) and the *Senatsverwaltung für Stadtentwicklung und Umwelt* (SenStadtUm). In this section, I will describe their general organisation and the functioning of the public lighting service, first in Lyon (5.4.1) and then in Berlin (5.4.2).

5.4.1 The cohesive and expanding Lyon public lighting network

Compared to other cities in France and Europe, the Lyon light planning and public lighting service is rather exceptional. So far, the *Ville de Lyon* has resisted the trend to privatise its public lighting service—like Toulouse and Lille, but unlike Paris and Marseille.

The *direction d'éclairage public* has about one hundred employees. The city has no financial problems as it is an economically prosperous place. 'Lyon is quite rich' explains the DEP director in front of a European delegation and adds that the budget for urban lighting has been stable since 1989 (NSR, 2011-12-06).

The DEP's service to the public includes the planning and maintenance of street lighting as well as decorative illuminations of buildings and fountains. They also look after electrically connected street furnishings like public clocks, telephone boxes, illuminated bus stops or street panels and floodlit sport areas. Last but not least, they are also in charge of temporary interventions in public spaces that require electricity connections, like markets or festivities (DEP, 2004). In this respect, the above-described light festival is the most important festive event in the DEP's annual schedule. The urban community Grand Lyon is responsible where lights in green areas are concerned or the tunnels and motorways that lead through the city (Ville de Lyon, 2011, DEP head of maintenance, 2012-01-18).

The DEP handles all phases of lighting projects from decision-making, to planning, realisation and operation. Only installation works are outsourced (DEP, 2004). The DEP director heads six operational units in charge of administration, organisational management (*méthodes et moyens*), security, technical planning, logistics and maintenance. The technical planning office, the so-called *bureau d'études*, supports light planners, supervises or carries out the planning of new installations or the refurbishment of new equipment. The planning office also specifies materials and services for public procurement. In decorative lighting projects or larger urban renewal projects the DEP also commissions lighting designers to carry out the planning.[271] The *bureau d'études* is not only in charge of the project development (*la maîtrise*

[271]The commission of external light planners was institutionalised with the first light plan. While the DEP lost some of its power and freedom to design the organisation also gained in expertise. The director of the DEP described their collaboration with private light planners, designers and technicians in the planning phase of projects as an 'interesting set-up because it allows for many exchanges within the pool of partners from planning to realization. It is a mutually enriching experience to work with people from different backgrounds, to share different experiences, as well as approaches or ways of thinking which are different from those you might have internally' (quoted from Marescaux, 2002) .

d'œuvre) but also accompanies installation projects in the realisation phase (*la maîtrise d'ouvrage).* New installations like the ones described above are carried out by contractors who do the excavation and purchase, deliver and mount the materials. These firms have long-term contracts with the DEP. The municipal maintenance department supervises their construction work.

When installations are completed and approved by the *Bureau d'Études,* the DEP maintenance department takes over the *régie*, that is, the operation and maintenance. The maintenance service presents the largest unit within the DEP with approximately two thirds of the overall DEP staff. The maintenance service is subdivided into four units that are each responsible for a part of the city.[272] Operations and workflows are documented and harmonised in a central data base. The maintenance software allows the DEP units to coordinate their work and keep track of installation activities and interventions like repairs, cleaning and planned lamp replacements.[273]

The public lights in Lyon are checked at least once every trimester. If the traffic permits it and they have the equipment on board they also replace broken lamps and repair malfunctioning infrastructures on the spot (DEP head of maintenance, 2012-01-18). Every night, two DEP cars tour the city and look for technical defects.[274] The main routes of the city are controlled once or twice a week. Smaller streets receive less attention. The long stairways which connect the quarters alongside the benches of the Saône and Rhône with the residential areas on the hills of Lyon are difficult to maintain because the technicians have to patrol them on foot and cannot use hydraladders to clean and exchange materials (ibid). Finally, responses and complaints from residents help to detect errors. But the DEP receives only about a dozen emails or calls per week, while the electricians and workers of the maintenance department sort out approximately 80 problems per week. '*We* detect more,' remarked the head of maintenance jokingly (2012-01-18). They also react quickly. The reply time is about 24 hours (GOJA, 2011).

[272] The maintenance service, located in Vénissieux in the 8th district in the south of Lyon, is also spatially separated from the *Bureau d'Étude,* the logistics unit and the head office, which are situated in the 9th district Vaise at the opposite site of the city.

[273] Since 2010, the DEP uses a modified version of standard software that is used by municipalities for managing their urban networks. Its modification and adjustment to the DEPs needs was, according to the head of maintenance, 'very, very laborious' (2012-01-18). The new software adds a time dimension to the spatial representation of lighting materials and urban geography.

[274] Before the weekly working hours were reduced to 35 hours there were eight night shifts. Four teams with two DEP technicians patrolled the streets of Lyon in their vans nightly.

Within the city administration, the DEP is integrated in the urban development department, which is also in charge of urban renewal, green spaces, urban mobility and urban economic development (Ville de Lyon, 2011). In larger urban development projects and where the main traffic axes, tunnels, green spaces are concerned, the City of Lyon works together with the urban community Grand Lyon. The above-described light plan serves as a shared reference for decision making and project planning.

Generally speaking, work flows and cooperation between the DEP and its contractors are well established and seem to function well. Talking to private actors I found that they highly respect the municipal employee's competence in lighting. Vice versa, the civil engineers seem to be aware of their strong position as important clients in the region, demanding customers and experienced professional users (NSR, 2012-01-31).

But the Lyon public lighting network is not only cohesive but also expansive. Its planners are involved in a number of projects and activities in the City of Light. Apart from the Fête des Lumières, the DEP is also a member and actively engaged in the activities of the Lyon-based city expert network on urban lighting LUCI (*Lighting Urban Community International*). The network was founded in 2002 and includes cities, individual lighting professionals, like designers or consultants and organisations and sponsors from the lighting industry. It offers around one hundred members, thus providing a platform for expert exchange and networking. The LUCI head office in Lyon is involved in a number of EU projects on SSL and was invited to participate in the European Commission's 'EU Task Force on Solid State Lighting' (4.2.3). LUCI organises a number of network events and conferences throughout the year. The community meets annually in Lyon for the Fête des Lumières and the convention *Rencontre de la Lumière* (NSR, 2011-12-09b). Twice a year the members meet in one of the member cities to learn more about their hosts' public lighting strategy. This format, called 'City under the Microscope' (*»Ville à la Loupe«*), is particularly interesting in terms of direct expert exchange , 2014b). In addition to that LUCI commissions research on urban lighting and publishes best practice guides that provide municipalities word-wide with examples of city marketing with light festivals.[275]

The DEP is also in contact with the regional Cluster Lumière, which was founded in 2008. The Cluster Lumière covers 'the whole value chain of the lighting sector' in the Rhône-Alpes

[275] See all publications on: http://www.luciassociation.org/media-resources.html, last access 2014-08-29.

region (Cluster Lumière managers, 2011-12-21). It is particularly interesting for small and medium-sized enterprises as it offers them a platform for knowledge exchange, access to laboratories for testing and certifying their products, and networking opportunities. It also enhances LED co-development R&D projects.

Another innovation-related format is EVALUM (*Evaluation Lumière*), a series of transdisciplinary *in vivo* experiments carried out in public spaces in Lyon. Again the DEP was involved together with Lyon-based manufacturers and scientists from the local university and research centres.[276] Manufacturers provided the materials. Lighting engineers produced photometric data, geographers invited lay people to participate in night walks and give their opinion on how they perceived the light in space (Avouac, Deleuil, & Fontoynont, Nov. 2009; J. M. Deleuil, 2009). A civil engineer explained that the feedback from citizens was a crucial motivation for the DEP to launch the experiments:

> 'For lighting, they [citizens] weighed in very rarely except when there was a blackout. When they were in the dark then, yeah, it needed fixing or lighting. But when it came to quality, or comfort, they rarely weighed in. That's why we launched the EVALUMs... telling them "look what we can do." Because they were more or less satisfied with what they had at the time, but they didn't know what we were capable of doing, so they couldn't compare solutions. So we would propose several solutions to find out what suited them. Notably, this technique allowed us to see that there were energy-saving solutions that suited them too. So they would tell us "both solutions are acceptable," except where one consumed half as much energy as the other. So if both were at the same level in terms of quality, better opt for the one that consumes less energy. This allowed us to offer choices to the population. Whereas before, on the contrary, it was they who would give us feedback, that was mostly negative moreover, so...It's basically more of a two-way street. An exchange rather than just feedback. So that's why we set up this kind of experiment' (DEP lighting engineer, 2012-01-06).[277]

[276] The scientific evaluations were led by Jean-Michel Deleuil (INSA) and the lighting engineer Marc Fontonynont, head of the building science laboratory and light and vision group at the University of Lyon and professor at ENTPE (Ecole Nationale des Travaux Publics de l'Etat).

[277] OV : *« En éclairage on exprime très peu souvent à part quand il y avait des pannes. Quand… c'est dans le noir… voilà il fallait réparer ou … éclairer. Mais : sur la qualité, sur le confort, il s'exprimait pas réellement. C'est pour ca qu'on a lancé les EVALUMs … en leur disant «voilà ce qu'on est capable de faire. - Parce-ce qu'ils [les riverains] étaient plus ou moins contents par moment de ce qu'ils avaient et ils ne savaient pas ce qu'on est capable de faire ils ne pouvaient pas comparer entre les solutions. Donc on leur propose plusieurs solutions pour savoir ce qui, ce qui leur convenait. Et, notamment on a cette démarche parce que ça permettait parfois de voir qu'y avait des solutions plus économes en énergie qui leur convenait aussi. On nous disait les deux solutions sont acceptable sauf qu'y on avait une qui consommait deux fois moins d'énergie que l'autre. Donc, si les deux étaient au même niveau de qualité on prend cette qui consomme moins d'énergie. Ca permettait de proposer des choix à la population. Tandis que, avant à l'envers, c'était elle qui nous faisait*

Finally, the DEP light planners not only provide a public service but also export their competence. The director of the DEP was asked by the French Ministry for the Environment to give his opinion on their new legislation against light nuisance (cf. Morgan-Taylor, 2015) In their professional peer group, the Lyon experts play a leading role in the public lighting group of the *Association des Ingénieurs Territoriaux de France* (AITF), the French civil engineering professional association. Until 2012, the DEP chaired the regional working group Rhône-Alpes, which means that the DEP organised and moderated the 'more or less' quarterly meetings (DEP head of maintenance, 2012-01-18).[278] In addition to the national professional exchange, the DEP also exports its expertise internationally.[279] Lyon lighting engineers planned and supervised projects in St. Petersburg (Russia), Havana (Cuba), *Hồ Chí Minh* City (Vietnam), Setif (Algeria) or Frankfurt/Main (Germany) (Chabert et al., 1999; NSR, 2011-12-02b, 2013-09-19). The situation could not be more different in Berlin.

5.4.2 The dispersed and downsized Berlin public lighting network

In contrast to Lyon, the Berlin public lighting service is organisationally distributed and rather shrinking than expanding. The legal responsibility to light Berlin's streets lies with the government of the city state, the Land Berlin, more precisely, the civil engineering unit X within the Senate Department for Urban Development and the Environment (*Senatsverwaltung für Stadtentwicklung und Umwelt*, in short, SenStadtUm).[280] However, light planning, operation and maintenance are outsourced to a private managing firm, private light planners, installers and maintenance teams. Although the decision making competence lies with SenStadtUm and, if necessary, with the Berlin Parliament, standard projects are mostly initiated and planned by the civil engineering units of the 12 Berlin districts[281] in cooperation with private light planners (SenStadtUm civil engineers, 2012-12-05). After new installations are completed and approved the legal responsibility is transferred from the

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remonter uniquement des remarques la plupart du temps négative d'ailleurs manque, ces dépense manque là. C'est un lien un peu plus… bidirectionnelle, quoi. Un échange plus que... une remontée d'information. Donc, c'est pour ca que…a été mis en place ce type d'expérimentation » (DEP lighting engineer, 2012-01-06).

[278] According to the then national AITF chair, the Rhône-Alpes group is the only regional public lighting AITF group that meets regularly (municipal consultant, interview, 2012-02-03). He also pointed out that the DEP's special contribution to the group was facilitated by the fact that the director dedicated time and also assigned his staff's time budgets to this exchange.

[279] To facilitate their international export, the DEP created new organisational structures that allow them to operate outside the narrow administrational municipal structures (NSR, 2012-01-25).

[280] The legal responsibility is laid down in the Berlin road act (BerlStrG, 1999-07-13).

[281] In 2000, the 23 post-reunification districts were restructured and merged to form only 12 districts. The administrative reform became effective on January 1st 2001.

district-level to the Land Berlin (Berlin lighting engineer, 2012-12-13).[282] As outlined above (5.3.2), the Berlin light plan is designed to coordinate the collaboration between SenStadtUm and the districts by establishing rules and procedures.

The fundamental differences between the public lighting services of Berlin and Lyon is most obvious in the number of municipal employees in charge of public lighting. While the DEP employs approximately hundred people, the SenStadtUm civil engineering unit is a team of six (SenStadtUm civil engineers, 2012-12-05). The team has been and still is heavily affected by the post-reunification restructuration of the Berlin administration and downsizing.[283]

The SenStadtUm team supervises modernisation processes or larger installations, for instance regeneration projects that are funded by the EU. They also control the private firm that operates the public lights. The current manager started its work in October 2011. The terms and condition of the collaboration between the Senate and its light manager is laid out in a seven-year management contract. As the director of the Senate unit explains, ‘we commission, control and pay them but the manager coordinates the actual business out there on the street with a whole legion of subcontractors’ (SenStadtUm civil engineers, 2012-12-05). The light manager is bound to outsource installation work by contract. The respective clause is meant to protect local small and medium enterprises. Accordingly, a large number of subcontractors is supervised by a small private light management team which is itself supervised by a small municipal unit at SenStadtUm.

‘The manager’ only employs a team of 17 office workers, business administrators and lighting engineers. They coordinate installation projects, deal with manufacturers, suppliers and contractors and advise SenStadtUm in public procurement decisions. They also receive the phone calls and error reports from citizens (head light manager; 2013-06-10). The electric lights are checked every six weeks by subcontractors, the gas lamps once a week. There are approximately 3,000 electrical failures monthly, in other words about 10 times more than in Lyon. The gaslights perform even worse, which is one of the key arguments for its replacement.

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[282] Before handover, the private light manager, the construction manager and sometimes also a SenStadtUm representative meet on site and check the new installation. If there are no defects or problems, SenStadtUm takes over the responsibility and the light manager the operational control (NSR, 2013-05-29; Berlin lighting engineer, 2012-12-13).

[283] According to the head of the unit there used to be 25 employees. In 2013, the Senate departments were again asked by the Senate to cut their positions by 15 per cent (NSR, 2013-05-31).

The additional subdivision of private management and maintenance makes the Berlin contracting model rather unusual.[284] A light planner describes the Berlin model as 'curious'(NSR & Toschka, 2013-05-29). The curious and also problematic organisational set-up is a result of past and present development. In the early 20th century, the public lighting service in Berlin was provided by Bewag, Berlin's municipal electricity utility.[285] After the devision of the city into East and West Berlin, the company and the gas lighting infrastructures were devided, too. In the eastern part, Bewag was renamed VEB in 1978. After the reunification of Germany and Berlin in 1990, Bewag was also reunited (ut, 2011-04-12). Until 1997, the Land Berlin held the majority of the private company's shares. When municipal energy utility was privatised, the organisational structure of Berlin's public lighting was restructured as well. An external assessment and comparison with other cities confirmed the suspicion that the Bewag's public lighting service was indeed very expensive. The public lighting department had offered a good service and quality at a high price. They had tested lighting equipment and developed guidelines that were also recognised outside Berlin (head light manager; 2013-06-10). Yet their service had its price and all their expenses were refunded by West Berlin. After reunification, they had tried to 'slim down' but the discrepancy between the status quo and a lean public lighting management was still too big.[286]

In 1998, the Land Berlin published an invitation to tender and became a pioneer in the privatisation of public lighting in Germany (head light manager; 2013-06-10). Since then, the actors of the Berlin public lighting network seem more preoccupied with themselves and their collaboration than with the public lighting infrastructure of Berlin.

In 2000, Berlin's electric public lights were handed over to a private light manager.[287] In 2001, the same company also took over the gas lighting, which had so far been serviced and maintained by the Berlin Gasag.[288] The cost could be reduced enormously—in an order of 50

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[284] The EU report ‚Lighting the Cities' outlines three models (European Commission, 2013-06):1) Lighting contracting – 'a pure service model, where the lighting system ownership remains with the public authority.' 2) Light supply contracting – a complete transfer of the system to a private company. […] 3) Energy performance contracting (EPC) –'a combination of elements from the above two models.' Berlin is a special case

[285] For a more detailed history of the Bewag that was originally founded in 1884 by the German Edison Company see Hughes (1983) and Hasenöhrl (forthcoming).

[286] A former employee recalls that they worked in three shifts, early, late and night. Up to five municipal maintenance teams with two montage workers each were on the streets every night to check and service the lighting. The wages were more than fair, and those who worked night shifts were paid night surcharges on top. 'You cannot imagine how much money they earned' (Berlin lighting engineer, 2012-12-13).

[287] The private energy company that had bought parts of the Bewag came only second in the competition. Competence was not lost, though. Former employees found positions in the new company.

[288] After reunification, the former West Berlin gas utility Gasag first took over the East Berlin BEAG and was then also privatised step by step (Schuster, 2006)

per cent. Since the privatisation, the light manager has changed several times between three different firms. Between 2010 and 2011 Berlin's lights were managed on the basis of interim agreements due to an ongoing legal disputes about the transparency of the tender and bids. In the meantime, the lighting infrastructure was barely modernised. In 2011, the current managing company, which belongs to the local energy supplier and had won the tender with an extremely inexpensive bid, signed a seven-year contract with the Land Berlin. According to the head of the team, who started his career as a Bewag employee, the new start was 'exciting'—with 20,000 failure and trouble reports and more than 1,000 old damages. Thus, the privatization had not only positive financial effects but also produced negative material effects in its aftermath.

The current contract incentivises the light manager financially to reduce the energy consumption and maintenance costs of Berlin public lighting. As outlined above (5.3.2), a modernisation strategy was part of the tender but now proves problematic. The conflicting views regarding the appropriate energy-efficiency strategy slow down the infrastructural modernisation. If the manager proposes a technological solution for public procurement which SenStadtUm does not accept, the manager has to come up with a new plan and new calculations. 'The manager is not entitled to demand that we realise the modernisation plan,' explained a civil engineer (2012-12-05). But infrastructural investments in Berlin are also delayed due to temporary budget freezes and organisational problems within SenStadtUm. Interview partners indicated that SenStadtUm is lagging behind with the public procurement and tendering procedures.[289] Municipal actors blame the Senate's austerity policy and the internal organisational restructuration.

In addition to that, the management contract has loopholes. The manager is paid an all-inclusive sum *(Managementpauschale)* for ensuring the functioning of existing working infrastructures. This includes the replacement of old and broken lamps, the repair of damaged masts and the servicing of Berlin's care-intensive gaslights. However, some installations, especially gas luminaires, are so outdated that simple replacements of gas sockets or batteries will not solve the problem. The manager argues that 'repair service is only when things can be repaired' (head light manager; 2013-06-10). If it is necessary to take luminaires down and to request product offers from manufacturers, so the rationale, this is not part of the contract and

[289] These procedures follow the European public procurement law. 'Green' public procurement guidelines were just being implemented. See: http://www.berlin.de/vergabeservice/allgemeine_infos/vergabeleitfaden.html.

has to be paid extra. Obviously, the difference between repair service and refurbishment is debatable and leaves room for interpretation.

Against this backdrop, municipal and commercial actors both reminisce about the 'Bewag times' in West Berlin when everything was done to ensure the quality of Berlin public lights—and everything was paid by the West Berlin Senate. They refer to it as an 'all-round carefree package', which now belongs to the past. The head light manager pointed out that 'SenStadtUm cannot expect an all-round carefree package because the contract doesn't cover it' (2013-06-10 #2297). He further explained:

> 'The contract just bars a lot of things. Or everything requires additional agreements. That's a way of thinking with which the Land Berlin has its problems and, of course, we in part, too. [The civil engineer] always says „just quickly do it". I say "No, I don't get paid for that." "But you only have to change a mast." "Yes, but if we weren't there you would have to commission an engineering office." He would also drive there. He would also have a look at the mast and then drive home to make a drawing and then ask [the energy provider] to change some electricity connections. We have the same expenses.' (head light manager; 2013-06-10)[290]

SenStadtUm seems to have difficulties in accepting the deal they have signed. A civil engineer complains that one needed a consultant to interpret the contract.

The problematic contract is only one symptom of the underfunding of the Berlin public lighting network. It is an open secret that neither the management budget nor the prices of the private subcontractors cover the actual operation and servicing costs of the Berlin lighting infrastructures. The public lighting team has understood that they have signed in for a non-profit deal that is more politically than economically profitable for the light manager. Its strategic gain lies in driving local competitors out of the prestigious Berlin market. A civil engineer explains that 'for this price, it is quite impossible to render the services associated therewith' (2012-12-05).[291] The same applies to the subcontractors' and their servicing prices.

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[290] OV: *„Jetzt ist einfach Vieles ausgeschlossen durch den Vertrag, bzw. muss durch zusätzliche Vereinbarungen gemacht werden. Das ist genau die Denke, wo das Land Berlin immer Probleme hat und wir natürlich teilweise auch. Herr […] sagt ‚Mach mal schnell'. dann sage ich: Nee Herr […], das krieg ich nicht bezahlt.' […] ‚Aber da muss man doch nur nen Mast umsetzen' Ja, aber wenn wir jetzt nicht da wären, dann müssten sie extra ein Ingenieurbüro beauftragen, der würde auch rausfahren, der würde den Mast auch angucken, würde nach Hause fahren, würde ne Zeichnung machen, würde hier […] irgendwelche Stromanschlüsse verlegen wollen.' Den Gleichen Aufwand haben wir auch"* (head light manager; 2013-06-10).

[291] OV: *„: …für diesen Preis kann man eigentlich die Leistungen, die damit verbunden sind nicht erbringen. […] NSR: Was haben die davon? SenStadtUm: „Das Prestige. Und […der Konkurrent] wird das nicht lange überleben"* (SenStadtUm civil engineers, 2012-12-05).

According to a lighting expert, the average maintenance rate per light point in Germany is €20. In Berlin, subcontractors offer their service for €7 per light point and less (NSR, 2012-11-27; NSR & Toschka, 2013-05-29). As a result, the cheap subcontractors cheat and do not carry out the service as they ought to.[292] Controlling subcontractors is difficult in a large city like Berlin, explained a civil engineer, especially if they are on good terms with the manager's personnel and are warned before random checks (NSR, 2012-11-27).

In 2013, it is difficult to tell whether the initial 'friction losses' (quote light manager) between SenStadtUm and the manager and the public procurement problems are temporary or will remain. We can conclude that the restructuration has indeed cut the costs of public lighting in Berlin enormously but at the expense of the urban infrastructure. Delays in the modernisation produce additional costs and, as we will see in the case studies, introducing LED light in Berlin is not as easy as it is in Lyon.

Summing up, we have seen that public lighting in Lyon and Berlin is enacted in mutable public lighting networks which involve public and private actors, old and new artefacts, imaginaries and issues. As we will see in the following case studies, the territory, topography, city images and nightlife of Berlin and Lyon build the background of early public LED installations (5.1), while *existing* lighting infrastructures (5.2), light planning strategies (5.3) and institutional settings (5.4) are actively mobilised in the course of innovation activities. As we have seen, Berlin and Lyon proved extremely different in all these respects.

While the year 1989 was a key date for both urban public lighting networks, they have developed in almost opposite directions since then. The Berlin situation is marked by austerity policies, institutional restructuration and a pressing need for infrastructural refurbishment. As a result, the Berlin public lighting network is dispersed, the relationships between actors and things are problematic and SenStadtUm is hampered in its developer's role and instead concerned with reestablishing working conditions internally and with its private partners. Finally, the Berlin light plan aims to preserve and mend what is already there. It is ambitious in the sense that it integrates the latest state of knowledge on urban artificial lighting from different disciplines but is controversial among those who plan and operate the Berlin lights.

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[292] A civil engineer assumes their servicing fee does not even cover the journey as a hydraladder alone already costs €40 per hour. Or they outsource their service to freelancers: 'White Russians' who are paid €1 per luminaire and 'if he does not manage to do 100 luminaires per day he only does 50 and says he has done them all.'

Meanwhile, Lyon has taken a quite different route. The third city of France has renewed its city image with a regenerating light plan. Renowned for its Fête des Lumières, the City of Lyon claims a pioneering role in nocturnal urbanism. This role is also reflected in the urban public lighting network which is expanding on a global scale. The Lyon expertise in lighting is reflected in well-maintained equipment and a functioning municipal service. The DEP is well connected and respected within the municipal administration, by its private partners and among lighting professionals internationally. If I was to describe the styles of light planning in the two cities, I would characterise Berlin as self-centered and Lyon as extroverted. Equipped with this information we can move on and finally see how LED lighting was introduced in Berlin and Lyon.

6. LEDs in Lyon and Berlin: Six early public installations

In this chapter, we will finally see how LED lighting was introduced in Lyon and Berlin. Every case study starts with a short introduction or case profile, in which I situate the cases between the two poles of testing and showing. Since my data vary, I then explicate my approach and sources for each case, followed by a short description of the socio-material situation of the installations, including a selection of images and plans in order to also give the reader a visual impression. In the next step I explain who or what played a role in the installation process. Each case study ends with a short summary of *what* was tested or shown in public. In an outlook I will sum up the commonalities and differences of the six projects.

6.1 Lyon case studies

The Lyon public lighting department DEP started installing the first LED fixtures in 2011. As we have seen in the previous chapter, the civil engineers of the City of Lyon have the reputation of being 'prudent' when it comes to LED lighting. This attitude was also reflected in the way in which they planned LED projects and installed the untested innovation in their streets.

As a result of both, Lyon's 'prudent' approach to LED lighting and their established urban public lighting network, their early public installations turned out according to plan and served the actors involved in producing the kind of evidence they were looking for. In other words, the Lyon projects showed a tendency to start as tests and end as innovation showcases.

During my stay I gathered information not only about the following three installations, but also about three more projects. These included a small pedestrian bridge with an *LED presence detection* system, an elaborate large-scale LED replacement of the *light source* inside a popular Lyon luminaire, and a small-scale standard installation of LED luminaires on a bridge over the Saône River, which I crossed on a daily basis. These early public installations would have also been interesting. Yet the following three projects seemed more significant for contrasting with the Berlin case studies.

6.1.1 Place Bellecour – putting LED light centre stage

The LED lights on Place Bellecour, a vast and central square in Lyon, were installed in October 2011 in the course of a larger urban regeneration project. The installation developed from a well-prepared *public technological trial* into a *demonstration*, which was recognised by relevant audiences, including potential future LED users. As the manufacturer puts it, 'Lyon is a junction'.[293] Accordingly, the LED installation on Place Bellecour was widely acknowledged by lighting professionals. Since its installation, the LED design received considerable public attention from expert audiences and even in the local media.

The project was implemented at a time when LED products had just become powerful enough to illuminate large areas and seemed reliable enough to be installed in a prominent public square. Nevertheless, the project was first fraught with uncertainty from the perspective of the urban technology users. The technology was therefore thoroughly tested and tried before it was installed *in vivo*. The LED luminaires were installed at a busy crossing point, in the literal as well as figural sense. The fact that the project was a large-scale regeneration project was crucial for the use of LED technology. As we will see, unresolved political issues and the involvement of numerous stakeholders in earlier planning phases led to long delays. When the planning team could finally tackle the lighting design, LED technology was mature enough to be considered as an eligible and interesting option. Today, the prestigious square is lit by a customised newly designed LED luminaire.

Data: expert interviews, conversations and observations

The sampling and inauguration events took place before my research stay. The project description is based on my own experiences and observations on Place Bellecour during both day and night-time (2011-11-08, 2011-12-08b, 2013-06-26b). Other sources of information were interviews and conversations with municipal actors (DEP lighting engineer, 2012-01-06), the manufacturer (NSR, 2012-04-15) and especially with the lighting designer (2012-01-09; 2013-06-08). As cited below, online resources including local media, municipal press releases and historic accounts of the emblematic square provided background information.

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[293] OV : *« Lyon est un carrefour […] le petit monde d'éclairage aide à communiquer les expériences»* (NSR, 2012-04-15)

The situation: A large-scale, long-term regeneration of a central public square

Place Bellecour is situated on the *Presqu'île* in the centre of the 2nd district of Lyon. The trapezoidal 62,000m^2 square fulfils the function of a centre—not in a political symbolic sense, like the nearby Place des Terreaux, where the Lyon City Hall and other political institutions are located, but in terms of urban mobility. Place Bellecour is a hub and orientation point: Looking down from the hill of the basilica *Notre-Dame de Fourvière* on the other side of the Saône River, the square represents a landmark (Figure 6-1). When standing on the square, no houses or trees obstruct the view of the basilica (Figure 6-2).[294]

Figure 6-1: Looking down at Place Bellecour from the *Fourvière* hill ©.

The square is also a hub because it fulfils connecting functions for both pedestrians and motor traffic. It links the inner city shopping and pedestrian zones *(Rue Victor Hugo* and *Rue de la République)*. The road alongside the square links the two river banks of the Saône and Rhône and the bordering districts *Vieux Lyon* and the *Guillotère* quarter on the *rive gauche* of the Rhône. Finally, Place Bellecour is also an important exit and entrance of two metro lines.

[294] By opening up sight axes, the square transcends its geographical location. Its *glocal* characteristics are also inscribed by the definition of Place Bellecour as Lyon's zero point, the point from where the kilometre distances to other cities are measured.

During the Fête des Lumières the crowds form long queues in front of the metro station and security personnel manages the masses. Events like the light festivals, public exhibitions or sports events take place on Place Bellecour throughout the year. The ceremonial usage is part of its tradition. The 'emblematic place' is as old as the Roman city of Lyon (Figureau & Adde, 2013-07-11). Its important ceremonial function is also reflected in a history of frequent name changes, including *Place Royal* and *Place Napoléon*, as a result of the epochal changes in French history.[295] Today, numerous statues and symbolic monuments on the square evoke historic and local meanings and traditions.[296]

Figure 6-2: Place Bellecour: A vast square and emblematic place in the centre of Lyon (CC).

In 1989, the square became the focus of the city's larger urban renewal program. The urban redesign process went on for decades, was marked by political conflict, and was stopped and reinitiated under the aegis of two successive mayors of Lyon. Felling and replanting the trees encircling the square was a key public issue. The local press accompanied the development. In the process, local stakeholders and residents were consulted.[297] Decisions were made on

[295] The ancient Place *Bella curtis* was first renamed Place Royale then became Place Louis-le-Grand, Place de la Fédération, Place de l'Égalité, Place Bonaparte and Place Napoléon before receiving its current name.
[296] For instance, the statue in the centre of the square representing Louis XIV is flanked by two figures that sybolise the two rivers of Lyon. See: http://www.pointsdactu.org/article.php3?id_article=1530.
[297] The Lyon administration describes the project as follows: 'Fruit of a long process of concertation with the district councils and local residents' associations the project […] is both, contemporary and respectful of the place, livable and aesthetically pleasing, despite all technical and architectural constraints that it was subjected to.' (my translation). See : http://www.mairielyon2.org/article-Bellecour-Sud-fait-peau-neuve-96-634.html#.UaYEG5wa5Mc

three political levels, by the urban community Grand Lyon, the City of Lyon and the town hall of the 2nd arrondissement.[298]

The illuminations around Place Bellecour were explicitly mentioned in the new Lyon light plan and are directly linked to the protection of Lyon's status as a UNESCO World Heritage Site (Ville de Lyon, 2004). While the renovation of the lighting was the responsibility of the municipal public lighting department (DEP), decisions were made together with the actors involved in the larger regeneration project, notably a landscape architect and the *Architecte des Bâtiments de France* (ABF), the national institution for monument protection. The manufacturer and an external lighting designer joined the project later. The Lyon-based lighting design office is committed to energy efficiency and sound technological solutions. In the negotiations about the adequate lighting equipment for the public square, the lighting designer acted as a spokesperson for LED light. Paradoxically, delays and the slow pace of the regeneration process paved the way for an innovative lighting project.

The Process: Delayed until the time for LED lighting had come

In order of their appearance: the square, political decision makers, trees, the DEP, Architecte des Bâtiments de France (ABF), a landscape architect, a Lyon lighting design office, an underground car park, a local luminaire manufacturer, asymmetric LED optics, customised LED designs, overvoltage protection devices, silent lay audiences, a local TV programme, the 'small world of lighting', a delegation of public lighting professionals, future LED users.

According to the light planner in charge, the process 'was shaped by politics.'[299] But the 12 LED luminaires on Place Bellecour also owe their existence to the specific socio-material situation. The constraints and problems that occurred in the planning phase were so complex that the process of redevelopment was prolonged. The regeneration project was put on ice for years due to internal political conflicts and civic protest, including a public controversy over the felling of the old trees that surrounded the square.[300]

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[298] http://www.20minutes.fr/lyon/157307-Lyon-Projet-en-cours-pour-la-place-Bellecour.php
[299] In the OV : *« C'est passé par la politique »* (NSR, 2013-06-08)
[300] The fight over the tree felling led the Mayor of Lyon to stop the urban regeneration project. His successor restarted the process in 2007. See: http://www.mairielyon2.org/article-Renovation-de-la-place-Bellecour--cher-mais-necessaire--96-363.html#.Ud_sIW2DSGc, last access on 2013-07-11. Old chestnut and plane trees were replaced by oak and lime trees. See: http://www.lyon-urbain.com/travaux-place-bellecour.html, last access 2013-08-22.

Choosing an external light planner also turned out to be problematic. In 1990, two offices won a public design competition. However, they both lost the DEP's favour before they could plan the lighting for Place Bellecour—one after publically criticizing the DEP's lighting practice, the other after planning a project for the city that caused serious maintenance problems after its completion. Finally, the landscape architect invited a Lyon-based lighting design office and the DEP commissioned them to do the project. In the course of the process, another obstacle arose, namely an underground car park. Since the public-private contract between the city and the private car park operator is still valid, the city decided to avoid all underground construction works that could obstruct the parking business for fear of compensation claims by the private operating firm (Lyon lighting designer, 2012-01-09).

Figure 6-3: Cube-shaped luminaires as they can be found in many major streets in Lyon (CC).

While political, managerial and legal issues were pending, the project was on hold and the light planning delayed accordingly. In the meantime, LED technology reached market maturity as outlined in chapter 4. As a result, the lighting designers came up with an LED-based solution in their 2010 design proposal. More conventional solutions were already on the table, namely the lighting designers' first proposal—an indirect lighting fixture—and cube-shaped luminaires that had proven their functionality over the years (Figure 6-3). The DEP designers rejected the lighting designers' initial indirect lighting solution. They argued that an open fixture that would redirect and diffuse the light with mirrors was too difficult to clean and maintain and that leaves and dirt could fall into it and obstruct the light flow (Lyon lighting designer, 2012-01-09). The DEP's safe and, therefore, favoured solution was the masts with four cubes. Yet this choice was vetoed by the French monument preservationists of the ABF. The light planner recalled that the ABF representative argued that the cubed luminaires suited a motorway more than Lyon's prime location (ibid). In this situation, the lighting designer's new proposal, a customised LED luminaire that had not yet been produced nor tested, came into play.

The LED proposal answered particularly well to the DEP's technical design objectives, namely the question of how to light the vast square homogeneously and energy efficiently. For lighting engineers, the homogeneity of public lighting is an important quality criterion. As the human eye needs time to adapt to changing light levels, obstacles or living beings in dark zones can be easily overlooked, presenting a safety risk especially for car drivers. Although Place Bellecour is a pedestrian zone, the DEP was not content with the existing lighting. The old high-up luminaires bathed the area under the light poles in light and faded out in the centre reinforcing the impression of stark light contrasts. The objective was therefore to equalise the light levels on the square and to illuminate the centre of the square better.

In this respect, LED technology and its directional light output offered efficient new perspectives. In collaboration with a Lyon-based manufacturer, the lighting designer developed a luminaire design that combined six standard LED luminaire heads in one fixture (Figure 6-4). Every head contains 48 LEDs (colour temperature 3,000K) and is equipped with the manufacturer's newly developed asymmetric optical system.[301] The optical system seemed perfectly suited for Place Bellecour, where the light has to cross almost a hundred metres to reach the centre of the square. With its asymmetric light distribution, the proposed customized luminaire was designed to diffuse the light quite evenly over the square without over-illuminating its edges under the lamp poles.

[301] See: http://www.lonmark.org/connection/case_studies/documents/Bellecour_Place_Lyon_Streetlighting.pdf and http://www.weef.de/?section=projects&view=prj_entry&id=39&lang=09_us 2014-08-04.

Figure 6-4: Crowns of six 120W LED luminaires heads at a height of 15 meters ©.

While the ABF liked the elegant crown-shaped LED design, the DEP planners were still sceptical of the new light source. At the time, they had not yet tested LEDs in Lyon and lacked sufficient evidence or positive feedback on LED installations in other places. From the DEP perspective, it thus seemed highly unreasonable to install LEDs in one of Lyon's prime locations in the heart of the city, where technical failures would be most visible to the public.

The DEP needed evidence that showed that LED light was the best possible solution. Hence, the lighting designer organised a sampling. The temporary installation of different luminaires and light sources on Place Bellecour was a great success as it led to a unanimous decision. Both the municipal engineers and the lighting designer agreed that the LED luminaires' superb performance was obvious. They shed their light much more evenly over the square, so that the municipal engineers gave their consent to the untested technology. To be on the safe side though, they negotiated a ten-year warranty on the luminaires with the LED manufacturer, which is a very unusual agreement (lighting consultant, 2012-01-11).

In October 2011, the installation of the new luminaires was completed. A local TV channel broadcast the news (Tele Lyon Métropole, 2011-10-18). In the public version of the project, the homogeneous light levels are less important, while the energy efficiency of the project receives a lot of attention. Indeed, it saves the City of Lyon a significant amount of energy as the LED luminaires can be dimmed. After midnight, it is driven at half power and switched back to 100 per cent at 5 am.[302] Thanks to the homogeneous light distribution the reduced light levels are barely recognizable and the square seems still well-lit even if the lights are down by 50 per cent.

The project also found attention in the 'small world of lighting' (NSR, 2012-04-15). Shortly after its completion, the installation was a topic of interest during the Fête des Lumières in December 2011 when lighting experts and amateurs from all over the world visited Lyon. The Lyon festival is a fixed date in the calendar of the international urban lighting network. Lighting professionals talked about it in informal conversations (NSR, 2011-12-09c) and light designers showed it to an international delegation of LUCI members (NSR, 2012-01-17). Since then, the manufacturer has received several requests from cities and communes to reproduce the luminaire for their purposes in different sizes (NSR, 2013-06-08). Many cities wanted the complete package, explained the marketing manager including LED technology: 'In the long run, that's a lighting solution and not a product' (NSR, 2012-04-15).

Despite its visibility in the lighting scene, the LEDs on Place Bellecour seem to have remained invisibilised urban infrastructures. Residents were not invited to participate or give their feedback in the design process. When the planners installed the luminaires on the square, some passersby gave a positive feedback. The lighting designer recalls that those who stopped and talked to him found that the 'the square is finally lit' (2012-01-09). This is also an effect of the improved uniformity, which gives the impression that the light level has been increased whereas the fringes of the square are, in fact, less illuminated.

The light planners and civil engineers have also done their best to prevent technological failures. Negotiating a warranty with the manufacturer was one way to guarantee the long-term functioning of the LED luminaires. The warranty provides the DEP with security in case of failure making the LED decision more plausible for politicians and the public. In addition to minimising the political and economic risk, the light planners also reduced the technical risk of failure by taking precautions at the most critical point of the installation, namely the point where the luminaires' electronic LED system was joined to the city's large technical

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[302] http://www.lonmark.org/connection/case_studies/documents/Bellecour_Place_Lyon_Streetlighting.pdf, 2014-08-03. The manufacturer writes on his webpage that the lights are dimmed down at 11pm.

energy system (NSR, 2013-06-08). The light installation on Place Bellecour was connected to three different, partly very old, power circuits. Since LEDs use low voltage direct current, the voltage fluctuation in the alternating current of the urban electricity grid can destroy the light source. The energy supplier only guarantees its clients voltage fluctuations between 207 and 270V. The semiconductor chips only tolerate fluctuations between 220V to 240V, according to the lighting designer. They therefore built in a series of overvoltage protection devices. So far, there has been no problem (as stated in NSR, 2013-06-08). The warranty and the overvoltage protection are both part of the light planners' meticulous security measures for the public experiment. To prevent the publically exposed project from turning into a failed technological trial, they took precautions and were successful.

A configuration that works

The LED lighting of Place Bellecour is an exemplary case of adaptation in the sense that the new technology was not adopted but adapted. In the design process an existing technological feature, the LED optic, was recombined to a customized product and used for a site-specific installation in a very particular situation. Successful as it was, the project developed from a technology trial into a public technology demonstration for an expert audience.

At the same time, the new installation remained invisible to citizens, residents or tourists on or around the square. The gradual 50 per cent dimming of the lights at night was silently accepted without public complaints. The lack of reactions was not surprising to the planners as the human eye is barely capable of perceiving 50 per cent reductions in light levels, especially if they are dimmed steplessly. After observing the light changes on Place Bellecour on site, I can only confirm this claim. If I had not known and paid attention to it, I would not have noticed it.

The project was consequential in a twofold way. First, the actors involved learned and could confirm that LED lighting was indeed an energy-efficient and performant option to illuminate a vast square like Place Bellecour homogeneously. Second, the project also fulfilled a marketing function. The manufacturer's marketing manager reported that after the Place Bellecour project 'lighting professionals all over Europe, or at least in France, know that […]

you can have the same results with less electrical power' (NSR, 2012-04-15).[303] A number of cities and communes have shown their interest in the expensive and customised crown-shaped luminaire designed for the former Place Royale in the centre of Lyon.

6.1.2 Rue de l'Oiseau Blanc and Rue Thénard – unspectacularly new

Rue de l'Oiseau Blanc and Rue Thénard are two residential streets situated outside the centre of Lyon. In 2011, the Lyon public lighting department (DEP) decided to install warm-white LED luminaires in order to replace high pressure mercury luminaires (HPM) that then illuminated the streets in pale white light. The project turned the streets into *urban test sites* with the goal to learn more about LED lighting in practice and to see whether standard LED products on the market offered satisfying solutions for large-scale HPM-replacements, in other words, to gain experience and *build professional competence*.

The emphasis on testing, as opposed to showing, is reflected in the fact that the DEP deliberately chose two streets outside the city centre. They seemed remote and ordinary enough to escape public attention. In the case of technological failure or problems, only the residents would have noticed it and complained. Other than in the Place Bellecour project, technical issues are unlikely to turn into political ones in Rue Thénard and Rue de l'Oiseau Blanc. Furthermore, the streets presented rather *typical* urban settings for making first-hand and long-term experiences with LED lighting and for drawing general conclusions about LED technology as a replacement for HPM technology on a larger scale. The combination of peripheral situations and small-scale standard replacements diminished the public appeal of the early public installation in Rue Thénard and Rue de l'Oiseau Blanc.

Data: participant observation and conversations with experts and residents

The limited publicness of the LED installation cases also affected my data collection. The projects were neither intensively discussed, nor publically promoted. I therefore relied on observing the lighting professionals during their routine work. Both streets were refurbished in November and December 2011 during my research stay in Lyon. I visited Rue de l'Oiseau Blanc a few days after the LED installation in order to get an impression and talk to residents

[303] In the OV : *« ...pour les gens qui sont connaisseurs oui, ca… là oui c'est un projet réel. Parce-ce que ce sont des professionnelles de l'éclairage partout en Europe au moins en France savent que [...] avec moins de puissance on peut avoir le même résultat. »* (NSR, 2012-04-15).

(2011-11-29b). One week later, I joined the DEP project planners when they first visited both streets in order to examine the LEDs in place (2011-11-29a). Two days later, I witnessed the montage of LED luminaires in Rue Thénard (2011-12-01) and went back there, too, to speak with residents (2012-02-01). Interviews and conversations with DEP staff were complementary sources of information. For Rue Thénard I also received the manufacturer's LED product sheet and the technical planning document (Figure 6-6).

As my participant observations are complementary and the projects similar, I chose to draw all the information together and refer to two test streets in one case study. My data from Rue Thénard thereby supports my understanding of the replacement work on site. In Rue de l'Oiseau Blanc I learned more about the professional and lay evaluation of the refurbishment.

The situation: Standard refurbishment projects in peripheral residential streets

The test sites might be unspectacular but they are representative for many HPM-lit streets in Lyon. As outlined above (4.3.1) all streets that use that light source are due to refurbishment as HPM lamps will be phased out in Europe in 2015 in line with the EU Ecodesign Directive, just like the incandescent light bulb. Rue Thénard and Rue de l'Oiseau Blanc are situated in peripheral residential areas in two different districts of Lyon close the city's boundaries.

Rue de l'Oiseau Blanc is situated on the *Fourvière* hill. It is a narrow residential street with luminaires on one side only. The detached houses look modest. The cars parked on the streets are medium-sized and compact cars and a few SUVs. When I visited the street on a weekday around 7pm a number of residents returned home from work.

Figure 6-5: Rue de l'Oiseau Blanc in LED, Rue Thénard (right) in LED and HPM light (CC).

Rue Thénard is in a similarly peripheral and calm middle class area in the 8th arrondissement. The streets seem to differ in terms of private mobility. While in Rue de l'Oiseau Blanc, people came and went by car, Rue Thénard was more frequented by pedestrians. The commercial facilities in the vicinity of both streets support that observation: In Rue Thénard, a little corner shop is situated at the end of the street and open until late. In Rue de l'Oiseau Blanc, the closest shopping place is a drive-in fast food restaurant (10am to 11pm 7/7) on the main street a few hundred metres away (2011-11-29b).

The process: when innovation meets routine

In order of their appearance: Two peripheral residential streets, the Lyon public lighting department (DEP), the EU Ecodesign Directive, the Lyon light plan, old HPM luminaires, LED manufacturers, large pole distances, standard LED luminaires, residents.

The number of actors involved in the LED replacement in Rue de l'Oiseau Blanc and Rue Thénard was limited. The project was carried out by the 'the usual suspects' of the Lyon public lighting service. The DEP planned the two construction projects. Two different international luminaire manufacturers provided LED luminaires and local installation firms that have contracts with the DEP installed the material.

The two test streets are part of the DEP's experimental approach and larger innovation strategy, which also includes other LED test sites and public experiments EVALUM. The testing is reflected in the limited number of the installed LED luminaires. A DEP engineer explained their approach as follows:

> 'We're not going to buy four thousand… we're going to buy fifty to install them, to check them, to keep an eye on them, and see how they age. So it's a test, it's experimentation. But it's the real thing since we use it to light the street all year long and for the next ten years. This will be the installation that will be maintained.' (DEP lighting engineer, 2012-01-06)[304]

The choice of Rue de l'Oiseau Blanc and Rue Thénard was not only motivated by their remote situation and outdated lighting technology. According to the DEP director, there was also another 'very specific reason' to choose these two streets of all HPM-lit streets (2011-11-29a). As he further explained, they have very narrow sidewalks. In order to leave more space for pedestrians, the luminaires are fastened to the existing masts of the aboveground energy supply line for public lighting. But the distance between the poles is considerable.[305] As a result, it is difficult to light the street homogeneously with conventional technology. By using LED luminaires which have a more flexible light distribution, as we have already seen in the previous case study, the DEP tested whether the new technology could fill the dark gaps (*échecs*) in the illuminated street.

In Rue Thénard, the DEP even widened the pole distances in the refurbishment process, thus exploring the limits of the new technology: The previous 14 light points, which had stood closer on one end of the street than on the other, were replaced by only nine LED luminaires, levelling out the intervals between the light points to an equal but large distance.

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[304] In the OV : *« On ne va pas en acheter quatre mille …ee… on va en acheter une cinquantaine pour les installer pour vérifier, pour la surveiller, voir le vieillissement. Alors, ce du teste, c'est expérimentation. Mais c'est réel. Puisque on l'utilise pour éclairer la rue tout l'année et pendant les dix prochaines années. Ça va être cette installation qui sera maintenue »* (DEP lighting engineer, 2012-01-06).

[305] As mentioned before, the distance between light points is crucial for the use and evaluation of lighting technology. Large pole distances negatively affect the light distribution on the street. Since light spreads to all directions it will be more distributed and hence, weaker in the distance and bright under the luminaire. Manufacturers optimise the light distribution of luminaires so that they match with the shape of streets and the quality criteria in street lighting. Good performance means achieving an even light distribution and to avoid dark zones on the street. Dark zones are a danger to traffic safety since the human eye will adapt to brightness of lit zones and be unable to perceive obstacles in the dark. Yet, there is an alternative to brighter lights. Photometric test have shown that visibility is still high at low light levels if an area is homogeneously lit. Low light levels are increasingly attractive as they permit energy savings. In addition to that they are also in line with ecological concerns about light nuisance and the industry's interests in the promotion of LED products.

Figure 6-6: Five light points less for Rue Thénard and even larger pole distances (CC).

The LED products installed in Rue de l'Oiseau Blanc and Rue Thénard differ in their design and also with regard to their optical systems. They are innovative but off-the-shelf products, designed to become the standard lighting equipment of the future. At the time of the replacement, the choice of suitable LED luminaires on the market was limited. The DEP only ordered them in small numbers. Therefore, they were not obliged to publish a European public invitation to tender, but only compared three different offers (DEP head of maintenance, 2012-01-18).

The replacement in Rue Thénard took place in two steps at the end of November and the beginning of December 2011. First, the DEP exchanged only two luminaires. One evening, shortly before the remaining seven were due to be installed, the DEP director and his chief planner took a tour to examine the outcome. They were not perfectly pleased. The director criticised the bad uniformity of the LED lighting. There were 'black holes' on the street. The head of planning replied that this was the best they could get, given the large distances between the light points (2011-12-01). They considered whether they should stop the installation and look for more suitable products with a better light performance but then decided to finish the project as planned, despite the 'black holes', as they doubted that there were better LED luminaires on the market. 'There are limits', remarked a DEP engineer later in an interview (DEP lighting engineer, 2012-01-06).[306]

The installation of the seven remaining LED luminaires was scheduled two days later. It was carried out in a routine way by private contracting firms under the direction of the DEP maintenance manager for the respective areas. The installation also involved some

[306] In the OV: *« Il y a une limite à tout »* (DEP lighting engineer, 2012-01-06).

underground electronic de- and reconnection work on the public lighting electricity grid (DEP head of maintenance, 2012-01-18). A distribution box was removed from the narrow pavement in the street and two electricians reconnected the lighting power supply line to the distribution box in the street around the corner. The maintenance manager pointed out that the new power supply line will also allow adaptive LED lighting—'when the time has come' (2011-12-01).

The routine character of the installation was also reflected in the casual interaction between the DEP maintenance manager and the installers. The DEP employee visited the construction site only briefly to meet the subcontractors and check how their work was progressing. They chatted and joked around, and commented on the installation process. The installers worked on the narrow platform of a hydraladder *(Steiger,* see Figure 6-7) and the DEP manager and I were watching the montage process.

Figure 6-7: Routine installation works in Rue Thénard and an open new LED luminaire (CC).

In terms of technological trial, there seemed nothing to be tested or learned during the installation process. Although the two electricians in Rue Thénard mounted their first LED luminaires, they performed routine actions, as they said. The technological innovation was wrapped in the familiar design of standard luminaires, with the usual cables and screws and with all LED specific electronic components fitted into the lamp casing. In the course of our conversation, the installers opened the case of one LED luminaire and together we inspected how the LED modules, the electronic driver and thermal management were arranged inside the case. The electricians had no previous practical experience with LED technology in use but were informed about potential problems and uncertainties. Knowing the voltage fluctuations in the power supply, they expressed their doubts about whether LED light could really be so easily controlled and dimmed as manufacturers suggest.

In Rue de l'Oiseau Blanc, the DEP heads of planning visited and evaluated the new installations on a November evening shortly after the LED lights had been installed. They took rough photometric measurements and were pleased, even positively surprised, by the homogeneous and focused light distribution of the LED lighting. The average light level on the street was higher than they had figured and the lights did not shine into the front yards and windows of the residential houses in the streets.

This brings us to the residents, who live in the newly lit street but were irrelevant for the project. As in the case of Place Bellecour, the new lights did not raise the attention of lay audiences and did not open any socio-technical black boxes. One of the installers explained that the residents would have complained if they had found the new light unpleasant. 'The Lyonnais always say if they like it or not'. In Rue Thénard, a woman had even been content when the installers removed one of the old lamp posts in front of her house (2011-12-01).

In Rue de l'Oiseau Blanc, I talked to residents on a weekday evening shortly after the refurbishment (2011-11-29b). Seven out of eleven residents I met had noticed that the lighting in their street was different after the refurbishment. Four had not acknowledged any changes but also did not dislike what they saw.[307] All those who had realised the change appreciated them, referring to the light level ('the street was darker before'), light colour ('like on Christmas') and the light distribution ('before only one side of the street was lit. Now it is better lit and the houses less', in that case a couple's bedroom).[308]

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[307] These resident feedbacks are not representative since I have talked to too few people and without previous warning and proper introduction. It is possible that some of the residents just said they had not noticed anything to get rid of me.

[308] The residents used the following expressions to describe the lights: *« La rue était plus sombre »*, *«plus claire»* as opposed to *«plus faible avant »*, brighter but not cold—*«comme Noel »*, *«maintenant la rue est éclairée mieux et les maisons moins »…(*NSR, 2011-11-29b)

When I revisited Rue Thénard in January 2012 two months after the LEDs were installed, I learned that the refurbishment had been a topic of neighbourhood conversations. An astonishingly attentive resident gave me an accurate description of the new lights, its advantages and disadvantages: He knew that the DEP had installed LED luminaires and that they were 'very efficient' (2012-02-01). He and his neighbours found that the light levels were lower but they did not object because they approved of the energy savings. Furthermore, he pointed out that the sidewalk opposite the lights was now brighter lit than the side under the lights and showed me that we only had *one* shadow and not two as before. While the first effect resulted from the directed light distribution of LED luminaire and its open tilt angle on the pole, the loss of one shadow demonstrates that the light beams of neighbouring luminaires no longer overlap.

By comparing the feedback I got from residents we can see that the refurbishment had very different effects in the two streets. The LED lighting in Rue de l'Oiseau Blanc is perceived as brighter and warmer as the replaced HPM lighting, while the same switch of light sources, together with a reduction of light points, gives residents in Rue Thénard the impression of colder, fainter lighting. The DEP experts explain, that the two streets cannot be compared as they have tried different things—even larger pole distances—in Rue Thénard.

Test sites as part of a larger experimental framework

As we have seen, the two manufacturers involved provided off-the-shelf LED products, implying that they consider them as mature and sufficiently tested. We have also seen that the installers performed a routine job that involved little testing. The residents remained silent observers and were not considered as part of the DEP testing. Instead, the DEP designed the test sites as part of a long-term modernisation strategy and in order to reduce technical and managerial uncertainties of LED lighting. The testing did not end but only began with the DEP directors' site visits. Subsequently, the DEP maintenance continued monitoring the performance and operability of the new LED luminaires over their life span. The test streets are thus routine sites of intra-organisational, long-term evidence production. Theoretically speaking, the DEP planners thereby played a double role as they performed the part of LED spokespeople while they also evaluated the innovation as critical observers.

The test sites do not stand for themselves. The insights and experiences they are meant to produce are not site-specific but supposed to be more generally applicable to the operation of LED lighting and other residential streets in Lyon. Accordingly, the Rue Thénard refurbishment was completed although the DEP decision makers were not pleased with the homogeneity of the lighting—they might just use a different product *next time* (2012-01-25). In contrast to scientific technology testing, the DEP planners took only rough photometric values. In contrast to laboratory testing, where 'place is denied' (2.2.3), the site-specific socio-material settings mattered in the test streets. The DEP testing concerned not only the public *street* lighting but also accounted for narrow pavements and the light in front porches and on house facades. These socio-material environmental aspects are naturally considered in the DEP's valorisation of the innovation.

As such, the test streets Rue de l'Oiseau Blanc and Rue Thénard form part of the DEP's more general innovation strategy and a standard approach of experimenting, constant learning and intra-organisational training as outlined above (5.4.1). In the face of technological change and Lyon's energy reduction targets, the DEP is systematically exploring the advantages and limitations of LED lighting in order to stay ahead of the technological and political developments. However, they also challenge themselves: By trying out the innovation, they simultaneously test their professional competence and capacity to provide state-of-the-art efficient and high-quality public lighting.

The dramaturgy of the projects and their remote location suggests that the projects were *not* designed as public innovation showcases or for disseminating information. Instead, the DEP uses its insights and experiences internally. As in the case of Place Bellecour, the residents silently accept or even approve of the refurbishment. What they thought of the new light, in other words, their personal evidence production, was based on the subjective experience of the street where they lived and affected by what they knew about LED lighting.

6.1.3 Montée du Boulevard – a win-win situation

In the case of the *Montée du Boulevard* an innovative LED product was chosen for an original project in a highly specific urban setting, namely one of Lyon's public stairways. The lighting design responded to functional needs and integrated aesthetic considerations. Like in the case of Place Bellecour, the project developed from a *technology trial into a demonstration* of an innovative LED application. It was a test in the sense that the DEP commissioned the installation of the new LED fixture in order to try a more operable solution for those public spaces in Lyon that are inaccessible for maintenance vehicles and hydraladders. But it also turned out as a test case for the manufacturer when technical problems occurred in the course of the installation. On the other hand, the realisation of the project also gave the manufacturer the opportunity to show his new product in use. The company proudly presented the installation to its clients even before it was completed and functioned properly.

The specific urban site of the LED installation was crucial for both the choice of LED technology and its later public presentation. A lighting design office turned the project into something more than a mere maintenance issue, making reference to the unique urban situation and the meaning of the stairway for its local users. The concrete reference to the city and its inhabitants also allowed the manufacturer to flesh out advantages of the new LED product that go beyond the common pro-LED arguments like energy efficiency or claims to the longer life span of LEDs when compared to conventional sources.

Data: expert interviews, conversations and observations

When I first learned about the project in *Montée du Boulevard* I was already familiar with two of its key 'players', namely the LED products and the project designers. During Light + Building 2010, I had met the two lighting designers who were later commissioned to plan the project in the course of a guided tour through the trade fair. The tour was organised for an international group of LUCI members and led us to the exhibition area of the manufacturer of the free-hanging LED luminaire later to be deployed in *Montée du Boulevard* (NSR, 2010-04-14).

One month later I learned about the project rather accidentally during an informal conversation with the DEP head of planning (NSR, 2012-01-06). At this point half of the luminaires had already been installed in the lower part of the stairway. The project was completed after my departure from Lyon. Therefore, my account of the installation site is based on second-hand information and my own observations. My reconstruction of the case is based on conversations and interviews with the lighting designers (2013-09-20), the DEP planners (2013-09-19) and the LED product manager (2013-10-04). During two site visits, one in winter (NSR, 2012-01-18)[309] and one on a summer evening after dark (NSR, 2013-06-26a), I also talked to local people who use the staircase in their daily lives.

The situation: Transit zone between car-oriented city and bohemian quarter

Figure 6-8: Montée du Boulevard in daylight (CC).

The Montée du Boulevard connects the riverbank of the Rhône and the plateau of the *Croix Rousse* on the hill. The stairway thus also connects two very different areas of the city with very distinct urban atmospheres (cf. J.-M. Deleuil, 1994). The foot of the stairs is surrounded by a six-lane road along the Saône River, car tunnels and efficient high-pressure sodium

[309] I consider this one-hour stay on the staircase on a cold January night as my personal sacrifice for the sake of science.

lamps (HPS) representing the spirit of the car-oriented city (Figure 6-9). In contrast, the *Croix Rousse* quarter on the top of the hill is famous for its lively, alternative flair and associated with subculture, nightlife, gentrification and 'bobos' *(bourgeois bohemians)*.

Figure 6-9: Night life in the *Croix Rousse* quarter and the car-oriented areas of Lyon (CC).

The stairway winds up the steep slope in serpentines to the plateau. The path is encircled by walls, which form part of Lyon's 13th century fortification.[310] Back then, the bulwark that gave the Boulevard its name protected the city limits. It was only in the mid-19th century that the slope was embraced by the growing city. This former boundary function is still inscribed in the topography of the place, which is not easily accessible and leaves a remote impression. The stairway constitutes a pedestrian shortcut, but not the most inviting one. One must know that it is there, although its entrances are rather hidden. Walking down the stairs, the pedestrians' view of the path is obstructed by the serpentines and shrubbery, a lot of rubbish and dog dirt lie in the corners and the walls are full of tags and graffiti (Figure 6-10). Before the lighting was changed, the lit areas of the stairway were interrupted by dark corners and landings. A frequent user who knows the staircase well reported that strange things (*'des choses bizarres')* like drug abuse have happened here (NSR, 2012-01-18).

[310] http://ruesdelyon.wysiup.net/PageRubrique.php?ID=1003292&rubID=1003457, last access 2013-08-06.

Figure 6-10: An eerie place—the staircase at night and two young residents who like it (CC).

Despite its potentially eerie night-time impression, the short cut is much used by residents of the area. Old and young, women and men take the stairs on their way home. Joggers run up and down and young people even hang out here at night: During my summer visit (2013-06-26a) I met two students (see Figure 6-10, right), who are experts of the Montée. They live in the neighbourhood, come here twice or three times a week to meet with their pals and proudly introduced me to the 'special atmosphere' of the place: 'It is calm', 'nobody disturbs us' and there are no neighbours who could feel disturbed by them. Sometimes they stay until 4am in a small or bigger group, drinking, listening to music, smoking and playing cards. They had not paid attention to the new lighting. As mentioned before, the stairs are not accessible for vehicles making it difficult for the DEP to maintain or repair public lights.

The process: finding and tightening the *fil rouge*

In order of their appearance: A stairway between different urban realities, medieval walls, the Croix Rousse hill, roads and the Saône, pedestrians, runners, dogs, the DEP, a French lighting design office, canoe-shaped LED luminaires on a long cable, an international light manufacturer, installers, a professional magazine.

Acknowledging the important connecting function of the *Montée* and its uncanny situation, the DEP decided to improve the lighting on the stairway. However, from an operational perspective, this was not all that easy since installing new lights on the stairway was as difficult as maintaining them. Another objective was to replace the old HPM luminaires with more efficient light sources.

In an article about the project in the manufacturer's lighting magazine, the project goals are outlined as follows:

> 'Above all, the City of Lyon wanted a project that would meet people's needs. The previous lighting used old luminaires […] were difficult to access, making maintenance operations complicated and expensive. The light quality was poor, and the lamps were inefficient, and energy-hungry. It was obviously time to replace the old installation with sustainable, high-efficiency lighting that could meet pedestrians' requirements.' (Arnaud, 2013)

After the City of Lyon had decided to renew the lighting in the stairway, they published a call in which they described in detail what they were looking for. From the offers they received, they did not choose the cheapest but the most original proposal (NSR, 2012-01-06).

A French lighting design office from Marseille won the design competition and was commissioned to regenerate the night time image of Montée du Boulevard. The lighting designers proposed the free hanging LED solution which had been on display during L+B 2010. The luminaires had only been installed once before on a square in Eindhoven. The cable that holds and supplies the canoe-shaped luminaires can be lowered for repair work and cleaning and thus facilitates the maintenance of the fixture in the stairway.

The international luminaire manufacturing firm is based close to Lyon. The product manager described the installation as a pilot project due to its special requirements and situation. They were ready to make financial concessions, since the lighting system exceeded the municipal budget for the project (product manager, 2013-10-04). Thus, the DEP only 'paid a little' for the equipment (NSR, 2012-01-06) but took the risk of installing the new LED system in exchange.

The new lighting system consists of 26 LED luminaires and 12 poles that hold the cable with the luminaires. To position the poles for the cable without destroying parts of the medieval wall was a challenge. Therefore, an installing firm was already involved in the project in the planning stage.

The slender free floating LEDs were a constitutive part of the winning design. In their proposal to the City of Lyon (anonymised, 2012-04-04), the lighting designers highlighted several aspects of how the lighting fixture can regenerate and sublimate the distinct character of the place. Their vision for the project was grounded in their experience of the place and their observations during previous site visits.

The lighting designers characterised the site as a place that is experienced in motion, offering 'perspectives that open up different lines of sight', between the stones of historic walls and wild vegetation. They paid particular attention to the illumination of the *stairs* as a particular lighting task: In public spaces, they need to be illuminated for functional and security reasons and can thus positively contribute to pedestrians' sense of safety. At the same time, the illumination of steps creates an aesthetically interesting play of light and shadow. Thus, the garland of LED lights was designed to underline the features of the slope and winding path and add to the dynamic impression of the up- and downward movement. 'The light band links, traces' the walk down. It 'moulds the volumes'.[311] In their design proposal they describe their vision rather poetically (anonymised, 2012-04-04, my translation):

Débouler sur l'escalier	To tumble down the stairs
Gravir la montée jusqu'à la dernière marche	To ascend the rise
Flâner entre palier et virage	To stroll between landing and curve
Attendre sur une marche	To pause on a step
Et observer les corps nocturnes	And to observe the nocturnal shapes
Le fils rouge accompagne l'ascension	The leitmotiv accompanies the ascent

The design makes reference to the topography and the key characteristics of the urban site: The drop of the slope creates a great view over the river and the city. The zigzagging band of floating LED-lights is described as a *fils rouge*, a leitmotiv, that underlines the meandering course of the stairway as it winds up the hill. The connecting function of the path is also symbolically reflected in the attempt to light it well so that pedestrians can feel at ease and 'lift their eyes' to enjoy the sight of the old walls, the panorama of Lyon and the adjacent city Villeurbanne while descending from the *Croix Rousse* hill. The proposal points to the lightness of the slender LED luminaires and their 'discretion and better integration in the space' (anonymised, 2012-04-04).

[311] OV : *« Le lien lumière raccroche, suit, dans la déambulation. La lumière sculpte les volumes. »* (2012-04-04, pp. synopsis, my translation).

Figure 6-11: With the LEDs, the stairway was furnished with a new leitmotiv ©.

The lighting designers justify the choice of LEDs as their preferred light source by pointing to the technical advantages that facilitate the maintenance, including the supposedly long life span of LED luminaires and their good protection against external influences like water and dirt. They also point to the optical characteristics of LEDs, arguing that thanks to the focused light output, glare can be avoided in specific perspectives, which is an important argument for stairways where lights are perceived from different ground levels.

The project was implemented in two steps in the winter of 2011 and 2012, shortly after Place Bellecour and the above-described test streets. The site-specific installation asked for modifications of the LED system. To meet the DEPs colour temperature requirements (3,500 K), which are also part of the light plan, two LED types with different colour temperatures (3,000 K and 4,000 K) were mixed in the luminaires.[312] Yet the ‘more difficult’ part was ‘defining the metallic support for the cable while preserving the ramparts.’ (Arnaud, 2013) The installer and planners made a number of tests and calculations in order to define twelve anchor points for the luminaire cable without compromising the free floating impression.

[312] K means Kelvin. It is the measure for the light temperature. A white light source with 3000K is commonly perceived as ‘warmer’, a 4000K white light as ‘colder’.

Despite the preparations, technical problems occurred during the installation. For aesthetic reasons, the manufacturer had provided a non-standard cable with a round diameter. Standard cables are octagonal.[313] The provided cable did not match the standard fastening equipment for fixing the cable to the poles and walls. The material did not bend as it should and was damaged in the course of the installation. A DEP planner suspected that the manufacturer had tested his product only indoors at room temperature. When used outside in the cold (in December), the materials behave differently (NSR, 2012-01-06). The installation was stopped and continued after the manufacturer had provided a new cable for the fixture.

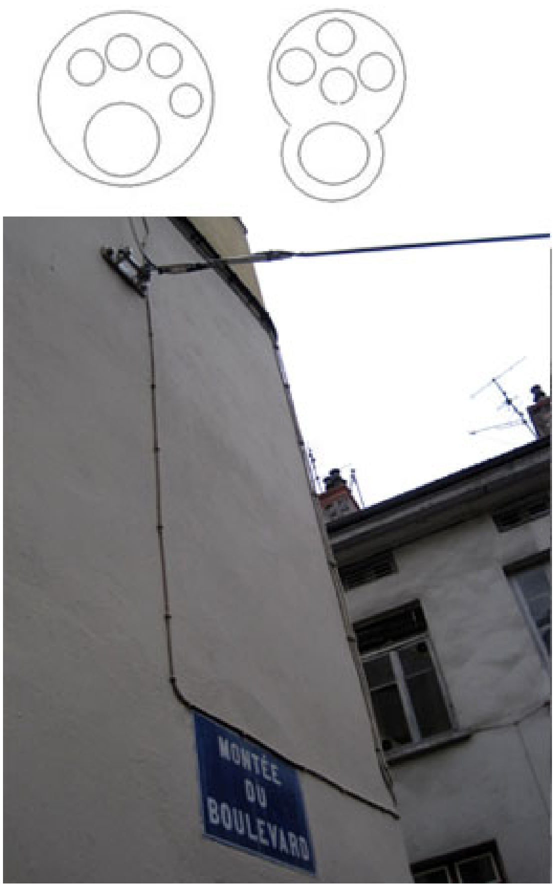

Figure 6-12: The octagonal cable and fixation points (CC).

For my field research, the interruption was a lucky coincidence as it allowed me to compare the old and new lighting on the spot and not only before and after. It was also interesting to see how little attention people paid to the change. During a one-hour site visit in January 2012 I talked to 13 people on the stairs. My standard question was whether they had noticed any changes in the lighting. Only two out of 13 had done so—a teenager who had also witnessed the installation works and a woman who lives right at the stairs, and whose entrance is now lit by one of the free-floating LED luminaires. The other pedestrians and joggers even had difficulty in noticing the difference when standing right between the old and the new luminaires. In my field notes I wrote:

> Pedestrian (early 30s): I meet a guy who has not yet arrived at the point where the LEDs start. I ask him if I can accompany him a few metres down the stairs—I may. I ask him to pay attention to the light and that it has been changed recently (he has not notices it yet). I do not specify my

[313] The big cable sustains and tightens the structure. The smaller ones are the plus the minus and the neutral wire and one is used for the remote control signal.

interest. As we descend he points at one of the really old luminaires and explains “this one is new”. I disclose the secret and point to the LEDs. He thinks the light is good. […]

Pedestrian (40s): A man who has not noticed anything and has already gone past the LEDs guesses: Is it the light that has changed? Is it more greenish now? He walks up and down the stairs 2 to 3 times a week. I tell him about the LEDs. […]

Pedestrians (mid 30s, mid 50s): The two men have not noticed anything. I point to the different light sources. The younger guy who is using the passage often says: "I would not have noticed it if you had not shown me". The other guy says he descends the stairs only rarely.

Figure 6-13: Montée du Boulevard before and after the refurbishment (CC).

In June 2013, I walked down the stairs under a garland of LED lights. One luminaire did not work but generally, the light level was brighter and more homogeneous than it had been before. In fact, the DEP engineers found the light levels too high and asked the manufacturer to provide them with dimming equipment. These negotiations between the manufacturer and the DEP went on long after the last official site visit of the planning team in spring 2013. The project was about to be completed in autumn 2013 when I last spoke to the actors involved (NSR, 2013-09-19; product manager 2013-10-04).

An innovation showcase with street credibility

The early public installation of the LED garland in Montée du Boulervard was clearly more an adaptation than an adoption of an innovation. The planning team visited the site several times before and after the installation. The LED product was modified to meet the municipal client's needs in terms of colour temperature. Furthermore, the manufacturer had to find a new solution for the cable and was asked to modify the light levels by providing a dimming device. According to the product manager such trials and errors are quite normal for a pilot project. They are also part of the development process of such 'rather conventional' and 'already known' product lines like the free-floating luminaires in Montée du Boulevard (product manager, 2013-10-04). After the project, the new cable has become part of the standard solution.

From the manufacturer's perspective, the Montée du Boulervard was an important demonstration project because it was the first in France and opened the French market (product manager, 2013-10-04). It was also widely communicated in the manufacturer's corporate magazine. In the article published in 2013, the new luminaire was promoted as a sustainable 'ergonomic solution' designed to 'guide pedestrians along the winding stairway without blocking their views'. 'The system offers enormous flexibility in terms of how it is installed, so it can be structured in response to the way people move and behave in a public space, rather than people having to adapt to where the lighting is located' (Arnaud, 2013).

In addition to the publication, the manufacturer has also taken interested clients to see the Montée du Boulevard turning the public spaces into a sort of open air showroom. The product manager remarks that the lighting designers, too, benefited from the demonstration project; and so did the DEP. The city looked for this type of application for other zones. The project showed them what they needed to know (product manager, 2013-10-04).[314] As a direct result of the installation, the manufacturer received several product orders from French cities, including Lyon. Based on their positive experiences in the Montée, the DEP decided to also use the LED systems in a regeneration project on the banks of the Saône River.

[314] OV: *« C'était un démonstrateur pour le concepteur lumière [...] et aussi pour la ville de Lyon parce-ce que la ville cherche ce type d'application-là pour certains autre zones qui soit récupéré. Voilà, ça leur a donné satisfaction. Donc, effectivement, c'était une petite opération d'état pour eux »* (product manager, 2013-10-04).

6.2 Berlin case studies

Like the Lyon civil engineers, the Berlin public lighting unit within the Senate Administration (SenStadtUm) installed their first LEDs in 2011. At the same time, the public-private Berlin public lighting service was affected by fundamental organisational restructuring and constant downsizing. The technological 'revolution in lighting' was not the most pressing problem SenStadtUm had in public lighting. Instead, SenStadtUm is still struggling with the administrative and infrastructural consequences of Berlin's division, including high public debt and outdated lighting equipment in West and East.

During my field research in Berlin, the following three LED projects were the only early installations in progress. As we will see though, the case of Saalestraße and Falckensteinstraße stands *pars pro toto* for a series of LED gaslight replacements. Strictly speaking, they all constitute individual early public installations. Yet since the political situations and technology is the same in all these projects, I have treated them as one case. The case of Altonaer Straße is also special in the sense that it was only a sampling event and the LED luminaires were only installed for the show. The project offered an interesting contrast to the other five cases.

6.2.1 Leibnizstraße – a failed municipal attempt to be progressive

The dimmable LED lighting in Leibnizstraße was the first LED lit street in Berlin. The lighting system was inaugurated in November 2011 only a few weeks after the LED luminaires on Place Bellecour. The project was designed as *experimental demonstration* project but turned into a *public trial* for its municipal developers. A municipal civil engineer recalls: 'Initially, we thought this would be a success story and we wanted to promote and present it.'[315] Yet the project did not meet the Senate Administration's high expectations. Retrospectively, the project planners consider it a failure although the LED lighting consumes little energy and works. 'I have seen much worse LED luminaires', said an expert on lighting technology. So why are the municipal project developers so disillusioned?

Looking closer, the project appears to have fallen apart in the implementation process. The diverging interests of the heterogeneous stakeholders were not successfully aligned. The

[315]OV: *„Wir hatten ja anfangs gedacht, das wird eine Erfolgsstory und haben Werbung damit machen wollen und wollten es etwas präsentieren"* (SenStadtUm engineer, 2012-12-11).

installation was a hybrid project from the beginning, partly envisioned as a technology demonstration and partly as a public experiment. On the developer's side, the politicised intra-organisational decision-making processes within SenStadtUm hampered the innovation-oriented technical endeavour. Ultimately, the key actors became dissociated from the project: The municipal spokesperson for the new light unexpectedly dropped out before the completion of the installation. The manufacturer moved on with newer LED products. SenStadtUm cannot fully exploit the expected energy savings and maintenance advantages due to structural problems that prevent the optimal usage of the LED telemanagement system. The scientists' field experiments also turned out problematic. Finally, the Berlin model case was not publically recognized as a successful Berlin LED showcase..

Data: interviews and 'second-hand' survey data

My account of the project is based on interviews and informal conversations with SenStadtUm employees (NSR, 2012-11-14b, 2013-05-22). In one interview, the manufacturer's former project manager who was in charge of the installation was present (2012-12-11). I also discussed the project and its results with the Berlin light manager (2013-06-10) and lighting engineers from the lighting technology department at the Technical University Berlin (NSR, 2012-09-12/13/14; SV, 2013, 2013-02-06). To see how they perform their measurements I accompanied them on one of their field trips (NSR, 2012-05-08).

I have visited Leibnizstraße several times. I did not question people about the new light situation since all residents in the street had already received a questionnaire from my colleagues at the 'Loss of the Night' research cluster. In the survey, urban planners and social scientists investigated the residents' perception of the public lighting in Leibnizstraße before and after the refurbishment. 96 residents responded before and 60 after the conversion from HPM to LED in Leibnizstraße, which is a response rate of 24 per cent (before) respectively 15 per cent (after, see Besecke & Hänsch, 2015). The survey was part of a comparative study and first presented during the 2013 conference 'The Bright Side of Light' (Schulte-Römer, 2013a).

The situation: Let's do something with LEDs

The LED installation in Leibnizstraße was initiated by the former head of the SenStadtUm public lighting section at a time when LED lighting had become the number one topic in conversations about public lighting. A civil engineer who joined the team just before the project start recalls the situation and their motivation:

> ‘The project came about because we had a very progressive boss […]. We as employees were always going to conferences. Everybody talked about LEDs. And Berlin was the only city without LEDs. It was then decided, to do something. Let's try' (SenStadtUm engineer, 2012-12-11).[316]

He further explained that they ‘said we try it because, ‘as the biggest light operator in Germany', they also wanted to ‘have a say' in professional discussions ‘when everybody talks about how great that [LED technology] is' (SenStadtUm engineer, 2012-12-11).[317]

To introduce LED light to the city, SenStadtUm chose Leibnizstraße. The street leads to Kurfürstendamm, is situated in the centre of West Berlin (Figure 6-14). It is also close to the offices of the public lighting section, which might have played a role (TUB lighting engineer, 2013-02-06). But there were more tangible reasons for choosing that specific location. The first was an infrastructural one: Leibnizstraße was lit by high-pressure mercury lamps (HPM)—like the Lyon test streets and Montée du Boulevard. According to a SenStadtUm civil engineer LED refurbishments are only cost efficient in Berlin when they replace outdated HPM or gas luminaires (2012-12-11). This is due to the fact that light levels had been reduced by half in the 1990s and therefore, as outlined above, consume little energy (see 5.2.1).[318] Another reason directly relates to the problem of innovating in public: The centrality of the street matched the municipal developers' idea of a pilot project in a prominent location. After all, the intention was to create a visible innovation showcase.

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[316] OV: *„Das Projekt kam deshalb zustande, weil wir einen sehr fortschrittlichen Chef [Name] hatten. […] Wir als Mitarbeiter waren auch ständig auf Tagungen. Überall wurde von LED gesprochen. Und Berlin war die einzige Stadt, in der es keine LED gibt. Da wurde dann beschlossen, irgendwas zu machen. Wir probieren mal”* (SenStadtUm engineer, 2012-12-11).

[317] OV: *„Wir haben gesagt, wir probieren das mal aus, damit wir als größter Leuchtenbetreiber Deutschlands, vielleicht auch irgendwo mitreden können, wenn alle erzählen wie toll das ist…“* (SenStadtUm engineer, 2012-12-11).

[318] OV: *„Wenn man eine Wirtschaftlichkeitsberechnung durchführt kommt man in Berlin zu dem Ergebnis, dass man LED einsetzen kann, wenn man von HQL [Hochdruck Quecksilberdampflampen] oder von Gas auf LED wechselt, ansonsten rechnet sich Umrüstung nicht, ist unwirtschaftlich“*(SenStadtUm engineer, 2012-12-11).

In the conception phase, the involvement of the lighting engineers at the Technical University Berlin (TUB) was decisive. The relationship between the Berlin public lighting professionals and the TUB department has long been established. The lighting engineers at the university give technical advice and test lighting technology for the municipal engineers who neither have the instruments nor the competence to perform scientific measurements. The former head of the public lighting team had regular exchanges with the experts at the university department (SenStadtUm civil engineers, 2012-12-05). As we will see, the TUB lighting engineers had a strong influence on the project.

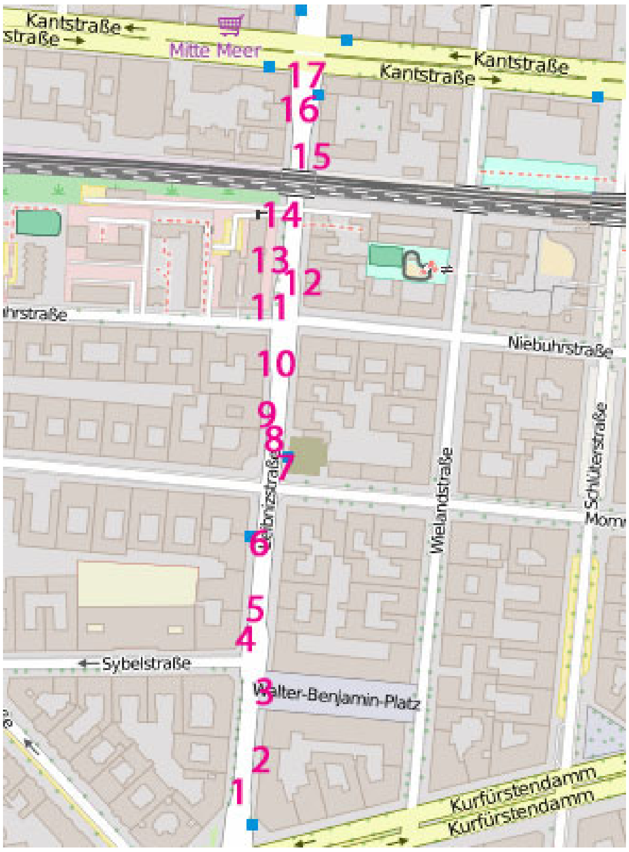

Figure 6-14: Project plan Leibnizstraße (CC).

The scientific engagement with Leibnizstraße was later further expanded through the involvement of the federally funded, interdisciplinary research project ‚Loss of the Night'. Ecologists, urban planners and social scientists made Leibnizstraße a field site in their inquiry into the positive and negative effects of artificial illumination.

The Process: from high commitment to disappointment and dissociation

In order of their appearance: the head of Berlin's public lighting unit, the TUB department for lighting technology, the Berlin Senate Administration, a central street, a dimmable LED system and its manufacturer, a transdisciplinary research cluster, residents of the street, the Berlin light manager, the Berlin electricity supplier, electricity metering devices.

The planning of the first Berlin LED project started in 2009. Public lighting services had begun to test the new technology and installed small-scale LED fixtures but there were still no definite results and very little practical LED experiences available:

> 'Everybody wanted LEDs and nobody knew exactly how they worked. Everybody tested sites, at this time. […] At the TU, they tested and measured LEDs for us and thus we started thinking "Yes? No? What advantages do they bring us?" LEDs are only lucrative if they have a kind of control system too…' (SenStadtUm engineer, 2012-12-11@my translation).[319]

As SenStadtUm lacked the LED experience and expertise to design a meaningful model case for innovative public LED lighting they relied on the TUB lighting technology department. The lighting engineers helped the municipal developers to come up with technical specifications and thereby gave the project a decisive twist. As close to manufacturers and technical problems as the lighting engineers were, they knew that LED technology was most promising and efficient when used in adaptive lighting systems. Yet the big question was: how will digitally controlled dimmable LED systems perform outside of the laboratory? Based on the TUB lighting engineers' assessment of the technological development, the public lighting section decided to make a case for digitally controlled LED lighting. This was also in line with the TUB scientists' research interests who hoped to use the installation as a test field for *in vivo* experiments.[320] As the head of the TUB department explained, such real-world photometric evaluations are highly relevant with regard to the development of LED products and new lighting standards for dimming lights in public spaces (see 4.3.2). While LED luminaires can be tested in laboratories, important risk and safety issues can only be addressed in real-world experiments, as—for instance 'how low can I go before it markedly affects the visibility?' (TUB lighting engineer, 2013-02-06).[321]

Within SenStadtUm, the project was controversial from the beginning. The head of the public lighting unit was, according to his team members, 'obsessed with technology' and the driving force behind the project against all opposition.[322] His superiors in the civil engineering department were not in favour of the project, even 'utterly against it' (SenStadtUm engineer,

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[319] OV: *„Jeder wollte unbedingt LED haben und keiner wusste genau, wie es geht. Jeder hat zur damaligen Zeit Teststrecken gemacht. Wir waren mit [dem Lichttechnik Professor] zusammen, die haben an der TU LED getestet und für uns gemessen und da haben wir angefangen zu überlegen, ‚Ja? Nein? Welche Vorteile bringt uns das?' Die LED ist nur lukrativ, wenn man gleichzeitig auch eine Art Steuerung hat..."* (SenStadtUm engineer, 2012-12-11).

[320] The lighting technology department relies on research assignment and publically funded projects, e.g. for creating positions for doctoral students (TUB lighting engineer, 2013-02-06).

[321] OV: *„Photometriedaten, die haben wir alle, aber [es fehlen] z.B. Sichtbarkeitsuntersuchungen, die eben aus meiner Sicht und für Dimmung interessant werden – was passiert eigentlich, wenn ich die Anlage dimme? […] „ wie weit kann ich denn runtergehen mit der Dimmung, bevor merklich die Sichtbarkeit einbricht?"* (TUB lighting engineer, 2013-02-06). Similarly, social-scientific research is needed to test the social acceptance of adaptive lighting, lower light levels or presence control (J. M. Deleuil, 2009; Schulte-Römer). I dare say that laboratory experiments alone will not provide the evidence that is needed to justify radically new 'intelligent' lighting solutions as they are projected for smart cities.

[322] OV: *„Er hat sich gottseidank nicht bequatschen lassen"* (ibid).

2012-12-11). The argument was that the technology was too expensive and that a pilot project did not make sense as Berlin had much graver public lighting problems than lagging behind in the LED development, namely the investment backlog and its outdated lighting infrastructures (NSR, 2013-07-31). It took months until the director gave his consent and 'dozens of endorsements' were filed before the project had passed the official intra-organisational channels and was officially approved.[323] Decision makers on the district level 'were not asked' (SenStadtUm engineer, 2012-12-11). As outlined above (see 5.4.2), the legal responsibility and accountability for providing street lighting lies with the Land Berlin (BerlStrG, 1999-07-13).

Figure 6-15: Leibnizstraße before the conversion to LEDs (CC).

The plan to do 'something' with LEDs took shape in the form of a digitally controlled LED lighting system. In 2010, the choice of trustworthy manufacturers who offered LED systems that fulfilled the project specifications was still limited. During the 2010 Light+Building trade fair, the SenStadtUm delegation visited the exhibition areas of eligible lighting firms. They looked for a LED standard luminaire that was suited for main streets in combination with a suitable telemanagement system. SenStadtUm chose an industrial partner with whom they had

[323] OV: *„[Der frühere Chef] hat uns vorangebracht, gegen alle möglichen Widerstände musste er dutzende von Vermerken schreiben, bevor wir erstmal die Genehmigung gekriegt haben, eine solche Anlage überhaupt aufstellen zu dürfen"* (ibid).

worked before. The manufacturer's project manager was well acquainted with the public lighting team and familiar with the Berlin public lighting situation, as he had worked for the city's private lighting manager before.

As in the case of the Lyon test streets, there was no need for a European public call for tender since there were few technical solutions on the market and no standard criteria to compare them (NSR, 2013-07-31; SenStadtUm civil engineers, 2012-12-05). By choosing a commercial partner one automatically chose a specific LED solution.

The LED luminaires in Leibnizstraße came with a wireless two-channel telemanagement system that allows remote controlled dimming and can, at the same time, send digital error reports back to facilitate maintenance. The envisioned cost benefit was twofold. The dimming would reduce the already low energy consumption of the LED luminaires even further. The feedback option in the telemanagement system may reduce maintenance costs and, if deployed on a larger scale, eventually even allow the light manager to dispense with a costly mobile error detection team (SenStadtUm engineer & lighting engineer, 2012-12-11).

In 2010, the TUB lighting technology department joined the transdisciplinary research cluster 'Loss of the Night'. The research programme was funded by the German Federal Ministry for Education and Research BMBF and investigated the economic, ecological, social and cultural effects of light nuisance.[324] In this context, Leibnizstraße was selected as a field site not only for photometric experiments but also for ecological field studies on the impact of LED light on the urban fauna and a comparative social-scientific case study. In 2011, ecologists installed insect traps in Leibnizstraße. Urban planners and social scientists sent a survey to the residents of the street before and after the installation of the new lights. Through the larger scientific framing, the public experimenting was extended far beyond light-technological assessments to also encompass the environmental and social aspects of the new lighting.

Meanwhile, a consequential change had occurred at SenStadtUm. The head of the public lighting team and driving force of the project had died. His successor seemed neither 'obsessed' with lighting technology nor personally closely related to the TUB lighting technology department, which seems to have weakened the crucial link between SenStadtUm and TUB lighting engineers as the spokespeople of LED lighting..

[324] http://www.verlustdernacht.de/startseite.html,.last access 2014-08-10.

Figure 6-16: Leibnizstraße in new light—presented on the luminaire manufacturer's website ©.

The first problems became apparent during the inauguration event. When the LED system was switched on in front of an assembled expert audience and local press, the light level had not been tested and attuned. Since the LED system was intentionally over-dimensioned, that is, had a higher light output than necessary, the street was too brightly lit when the lights were operating at full power.[325] As a result the audience complained about glare.

> 'We were caught on the wrong foot already in the very beginning […] Already on the first day, it was said "there is glare" and so on. We committed tactical errors there, I don't mind admitting it. […] The problem was that the press was already there' (SenStadtUm engineer, 2012-12-11).[326]

'It was more than bright', admits the manufacturer retrospectively, but blames his client SenStadtUm for not taking precautions:

> 'Since I had no order to reduce, I didn't do it, that's clear. I simply can't do it. During the inspection it was then determined, that the values should be entered [into the control system],

[325] LED systems are often over-dimensioned in order to be able to later counterbalance the degradation of the light points. In addition to that, LEDs last longer if they are not operated at full power.
[326] OV: *„[Wir] sind schon von Anfang an auf dem falschen Fuß erwischt worden. […] der erste Tag war schon so, dass gesagt wurde ‚das blendet' und so weiter. Da haben wir taktische Fehler begangen, das geb' ich gerne zu. […] Das Problem, dass dann schon die Presse da war."* (SenStadtUm engineer, 2012-12-11).

which we did the very same evening. And thus, the appearance is now very different' (Lighting engineer, 2012-12-11).[327]

Right after the unfortunate inauguration event, the luminaires were dimmed to 80 percent.

What is even more unfortunate for SenStadtUm is that the Berlin energy supplier has refused to account for the energy saved via dimming because the telemanagement system has not been equipped with an officially calibrated metering device. 'We could not convince [the energy supplier] to account for what we save', said the head of the team (SenStadtUm civil engineers, 2012-12-05). They further explained:

> '[N]obody has a plan how to calculate the electricity. We have a fixed remuneration (Pauschalvergütung). If I have a 100 Watt luminaire, I pay for 100 Watts. And if I dimmed to 50 percent during the night, I would still pay for 100 Watts. Hence I don't get anything out of the dimming.'[328]

Instead of measuring how much energy is really consumed, the Senate's electricity bill is calculated on the basis of the nominal installed connected load of the LED luminaires and their standard operation time. Although the LED system has been running on 80 per cent ever since it has been put into operation, SenStadtUm has paid for the full connected load. The public lighting unit has given up the fight and hopes that industry or government will eventually offer a global solution. The economic, environmental and operational advantages of digital telemanagement have so far not been exploited. The Leibnizstraße luminaires are switched on and off by radio ripple control, just like all the other 220,000 luminaires in Berlin (see 5.2.2).

Against this backdrop, SenStadtUm considers the project a failure. It 'failed because we did not come to a reasonable agreement with the energy supplier on how to account for the dimming.' But that is not the only problem. They further argue that the private manager of Berlin's public lighting was not interested in working with a new, expensive and faulty telemanagementsystem. The municipal actors also claim that the manufacturer lost all interest

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[327] OV: *„…da mir damals der Auftrag nicht vorlag, zu reduzieren [lacht], mache ich's dann auch nicht, ganz klar. Das geht auch nicht. In der Begehung wurde das dann auch festgelegt, dass die Werte so eingetragen werden sollen. Das haben wir dann an dem Abend auch gleich noch gemacht. Und somit ist das dann auch eine ganz andere Erscheinung"* (Lighting engineer, 2012-12-11).

[328] OV: *„…und dann hat niemand einen Plan, wie der Strom abgerechnet wird, wir haben hier eine Pauschalvergütung. und wenn ich eine 100 Watt Leuchte habe, bezahle ich für 100 Watt und wenn ich die nachts auf 50 Watt dimme, dann bezahle ich trotzdem 100 Watt. also ich habe nichts davon, vom dimmen."* (SenStadtUm civil engineers, 2012-12-05).

and has not solved or improved the digital system after the installation. Indeed, it made little sense, from a commercial point of view, to further invest in the small scale Berlin fixture. SenStadtUm has shown no sign of planning to expand the system. Furthermore, technological development has outpaced the LED solution deployed in Leibnizstraße. In fact, the technology had already been outdated when it was installed due to the long planning process and the rapid development of LED technology (SenStadtUm engineer and lighting engineer, 2012-12-11;NSR, 2013-07-13).

As a result, SenStadtUm cannot benefit from reducing the light levels, nor from operating the LED system intelligently due to the energy calculation problem. A SenStadtUm employee remarked to this: 'Yes, LEDs are dimmable. But the control system costs extra money – no chance!'[329]

The scientists also encountered research problems that are related to the *in vivo* situation and can be expected in real-life experiments. The photometric testing proved difficult. Although the installed technology would have allowed measuring *in vivo* whether or not obstacles on the street are still visible if the LEDs were further dimmed, the scientific work was obstructed by difficulties encountered on site.

Figure 6-17: TUB lighting engineers with luminance camera (CC).

The doctoral student in charge of the measurements found that there was too much light scattered on the street. He also did not come to terms with the Senate Administration to have the street blocked for one night. The photometric tests had still not been completed when I did my last interview (TUB lighting engineer, 2013-02-06).

The social scientists and urban planners saw themselves confronted with the methodological problem of designing a survey for laypersons on the invisible expert topic public lighting. In the survey residents were asked to give their opinion on the technological transition in their

[329] OV: *„Ja, die LED kann man dimmen, aber die Steuerung kostet einmal extra Geld und das ist überhaupt nicht drin"* (SenStadtUm civil engineers, 2012-12-05).

street before and after the conversion to LED lighting and their willingness to pay for better public lighting or more darkness. The survey questions addressed the residents' individual perception of the lighting situation in their residential environment, and their assessment of different functions of urban lighting, also in relation to the value of natural darkness.

The authors of the study, Anja Besecke and Robert Hänsch, found that their respondents 'are concerned about light, but on a low priority' (Besecke & Hänsch, 2015). After the switch from HPM to LED light, most of the respondents in Leibnizstraße perceived the situation as 'pleasant' while a quarter of the interviewees found it 'bright' or 'too bright' after the conversion.[330] At the same time, many residents in Leibnizstraße 'were not even aware of the new type of lighting,' that is the change from HPM to LEDs. There was also a high rate of 'don't know' answers, which the authors interpreted as a conscious expression of the respondents' lack of experience and knowledge. In line with these findings and also previous studies (LIT), the residents' monetary assessment of light and darkness, showed that their readiness to pay 'relates more to environmental issues like energy efficiency or ecological sustainability' than light levels (16/20). Besecke and Hänsch conclude that '

> 'Questions concerning the issue of lighting and darkness proved to be quite complex. Light possesses enormously diverse features and takes on a number of different forms within different spatial contexts. Moreover, there are considerable individual differences with regard to perceptions and evaluations of light and darkness – we could almost go as far as to say that they depend on people's "taste"' (Besecke & Hänsch, 2015).

The public lighting network on trial

The case of Leibnizstraße perfectly illustrates how public technology experiments that are meant to demonstrate that innovations work can turn into public trials for those who innovate. The failure of the public experiment can be considered as a symptom of the Berlin public lighting network, which was 'under construction' during Berlin's first public LED installation.

The organisational problems between the stakeholders and their unmediated heterogeneous interests led to a situation in which not the technology itself was tested, but the engagements

[330] Besecke and Hänsch write: 'Subsequent to the conversion to LED, a quarter of all urban interviewees evaluated the lighting situation as "bright" or "too bright". Compared to the "before" period, when a quarter of all interviewees assessed the lighting situation as 'dark' or "too dark", this corresponds to an increase of 7%.' (Besecke & Hänsch, 2015, p. 233).

and collaboration of the actors involved in the planning and operation of the installation. Accordingly, one of the SenStadtUm employees concluded: 'we have failed somehow. But that was due to the administrative system, and not due to the lighting system.'[331] Not the innovation was tested but the socio-material network which was supposed to stabilise it.

While SenStadtUm struggled with personnel changes and internal restructuring, the public lighting team appears to have underestimated the uncertainties that come with newness. Instead of testing first in private, they immediately presented their first LED installation in a prominent street in front of an expert audience and media without a previous rehearsal. Instead of showing innovation, they involuntarily presented their trial and error in public. As a result, the project did not demonstrate SenStadtUm's competence but revealed dysfunctionalities and asymmetries in the lighting professionals' relationships.

With regard to the scientific evidence production, the last word about the urban field site in Leibnizstraße has not yet been spoken. On the one hand, the results of the various projects are presently still being published (Meier et al., 2015). The research programme of the transdisciplinary Loss of the Night cluster only ended in 2013. On the other hand, the project also challenged the researchers in terms of designing *in vivo* research case studies and experiments. While the lighting engineers, who are used to laboratory experiments, struggled with the uncontrollable environmental conditions of the public street, the social-scientists had to consider the multiple factors that can affect residents' engagement with public lighting. Thus, and as will also be discussed below, the early public installation in Leibnizstraße raised new questions rather than showing that Berlin knew LED lighting.

The unfortunate outcome of the Leibnizstraße case is also reflected in its failure to produce the practical—and partly also scientific—evidence it was supposed to provide. Neither the private light manager nor SenStadtUm had an incentive to program and use the sophisticated telemanagement system. The dimming function was not fully exploited, the energy savings were not measured and SenStadtUm cannot present reliable figures about cost and energy savings in public.

[331] OV: *„Wir sind da irgendwo… Ich geb's schonmal zu, dass wir da irgendwo… gescheitert sind. Das liegt aber am System der Verwaltung, nicht am System der Beleuchtung."* (SenStadtUm engineer, 2012-12-11).

6.2.2 Saalestraße and Falckensteinstraße – imitating gaslight

The LED lanterns in Falckensteinstraße were not the first but, so far, the most public LED-fixtures in Berlin. This public installation of LED gas-light imitations was the culmination of a series of tests and attempts to mimic gas lighting with LED technology which also involved real-life tests in streets in Berlin Neukölln and Kreuzberg. One of them was Saalestraße. While these earlier installations can be considered as *urban test sites*, the well-prepared LED installation in Falckensteinstraße in November 2012 qualifies as a successfully staged *display of virtuosity*. The project was presented to the public in the course of two site visits, one for the local media and one for municipal monument preservationists. As such, the events formed part of the Senate Administration's strategy to close the public debate over the refurbishment and electrification of the famous Berlin gaslights (see 5.1.3).

In the politicised context of the gaslight conflict, the display was explicitly designed to engage wider lay audiences and to mediate between the conflicting interests of interested citizens, gaslight amateurs and urban preservation experts on the one hand and the Senate's wish to replace the outdated and expensive gas lighting on the other. In order to achieve that objective, the project in Falckensteinstraße was designed to produce evidence that was *visible* for anyone, and not only accessible to lighting experts. Paradoxically, this visible evidence had the intended effect of invisibilising the technological transition. By devalorising some of the gaslight amateurs' key arguments, SenStadtUm also diminished their chances to find new allies in their fight for the cultural good and the preservation of the 'Gasopolis' Berlin.

Data: Conflict - a researcher's gold mine

When studying public lighting in Berlin, the gaslight controversy cannot be overlooked. The public conflict facilitated my data collection. The gaslight protesters' emotional engagement and vigour opened a new perspective on public lighting, which I could not find in the other cases. Local and even national newspapers reported on the subject and provided me with sufficient material for a print media content analysis, the results of which I presented during the 2012 ESA conference in Berlin (Schulte-Römer, 2014a). In Neukölln, I witnessed how gas luminaires were replaced by LED luminaires in the course in an urban regeneration project in Saalestraße. There, I saw with my own eyes how well the new light mimics the old (2012-07-16, 2012-07-18). To understand the gaslight amateurs position, I attended a public debate

(2012-08-21), participated in one of their meetings (2012-11-14a) and have received their newsletter ever since.

Background information about the conflict and political decisions is available in the Berlin Senate's protocols and documentations (Abgeordnetenhaus Berlin, 2007-09-13, 2008-02-12, 2011-06-23). The modernisation and conversion strategy is outlined in the Berlin light plan (SenStadtUm, 2011). Additional information was collected in informal conversations with municipal actors (2012-11-14b, 2013-05-22). Technical information was provided during events (2012-04-25, 2012-11-16, 2013-01-25). After all, the topic is so public and relevant for Berlin's public lighting policy and management that it pops up whenever and wherever street lighting is discussed.

The situation: A new twist in a long story

As described above, the issue of the West Berlin gaslights has long been on the political agenda. The issue had been raised again and again by the Bewag lighting managers, on the district level and before the Berlin Senate. But it was only after the reunification and privatisation of the light management (5.4.2) that the Berlin Senate and the Berlin Chamber of Deputies, the Parliament, decided on the electrification of the city's public lighting infrastructure—against the express wish of concerned residents, including politicians, and civic groups, which had already formed protest groups in the 1960s. Among them are true lovers of gaslight, who have acquired a profound knowledge of both the politicised socio-technical system and the gas technology. Under the threat of an actual technological conversion the gaslight amateurs found new allies and reinforced their protest activities. They claimed that the lanterns and their warm-white light contribute to the uniqueness, look and feel of West Berlin Streets and are an invaluable part of the city's industrial heritage.

Their cultural perspective stood and presently still stands against the economic perspective of the private actors who plan and operate the Berlin public lighting and the SenStadtUm and the Land Berlin who pay the bill. Before the conversion, SenStadtUm stated that 44,000 Berlin gaslights consumed an annual amount of energy that was equivalent to the annual energy consumption of 180,000 electric light points. In addition, the gaslights were disproportionally expensive to maintain and hence difficult to operate.

Figure 6-18: The gas alignment luminaires are replaced by the electric Jessica (CC).

Therefore, SenStadtUm stayed committed to the electrification plan despite all civic protest. In 2007 the Senate filed a public lighting strategy, which was approved by the Berlin Parliament, (Abgeordnetenhaus Berlin, 2007-09-13) and included a twin-track strategy for the electrification of the West Berlin gaslights.

First, the Parliament approved the removal of more than 8,000 gas alignment luminaires *(Gasreihenleuchten)* in West Berlin's roads (Figure 6-18). A Berlin-based luminaire manufacturer won the public tender with a highly efficient electrical luminaire named *Jessica.* The removal of the error-prone and inefficient luminaires from the 1950s started in June 2012. The municipality has commissioned a private contracting firm with the management of the large-scale refurbishment (NSR, 2012-04-25). The construction works are accompanied and obstructed by gaslight amateurs' protests. They correctly argue that the high gas alignment luminaires are also part of the unique Berlin gaslight ensemble and try to prevent their removal with sit-ins. At the same time, the contracting firm is financially incentivised to carry out the transition quickly, since they participate in the profits from energy savings until 2017. The refurbishment is expected to amortise in about seven years (SenStadtUm, 2011).

The second part of the strategy concerned the refurbishment of the so-called pole-top gas lanterns *(Gas-Aufsatzleuchten)*, which were treated differently in the political debate. The lanterns are designed in the style of the 1920s and illuminate residential streets in districts like Neukölln, Schöneberg, Charlottenburg and Kreuzberg, including Falckensteinstraße.[332] In 2007, the political decision makers agreed that the lanterns have a historic value and are part

[332] In fact, the bulk of these gas pole-top luminaires of the so-called Bamag-U7 type date from the 1950s. They burn with four flames and many of them are still mounted on 19th century cast-iron bundle pillar masts. The lanterns with the metallic top came to West Berlin in the course of a systematic repair of the war damages from 1954 onwards (Grimm, 2012, p. 27).

of the urban image of West Berlin and its nocturnal urban atmosphere. The 2007 electrification plan was therefore limited to the replacement of the gas alignment luminaires and provided for the preservation of the pole-top lanterns. Yet in February 2008, the issue was back on the political agenda when the Berlin parliamentary group of the local Green Party filed a motion to revise the public lighting strategy with the aim to replace *all* gaslights in order to save more energy (Abgeordnetenhaus Berlin, 2008-02-12). The Berlin Senate expressed the political will to look for a technological solution that would allow them to electrify the lanterns without changing their design and light quality (Abgeordnetenhaus Berlin, 2008-06-04). The express wish to preserve the beloved lanterns and their warm glow opened a window of opportunity for LED lighting in Berlin.

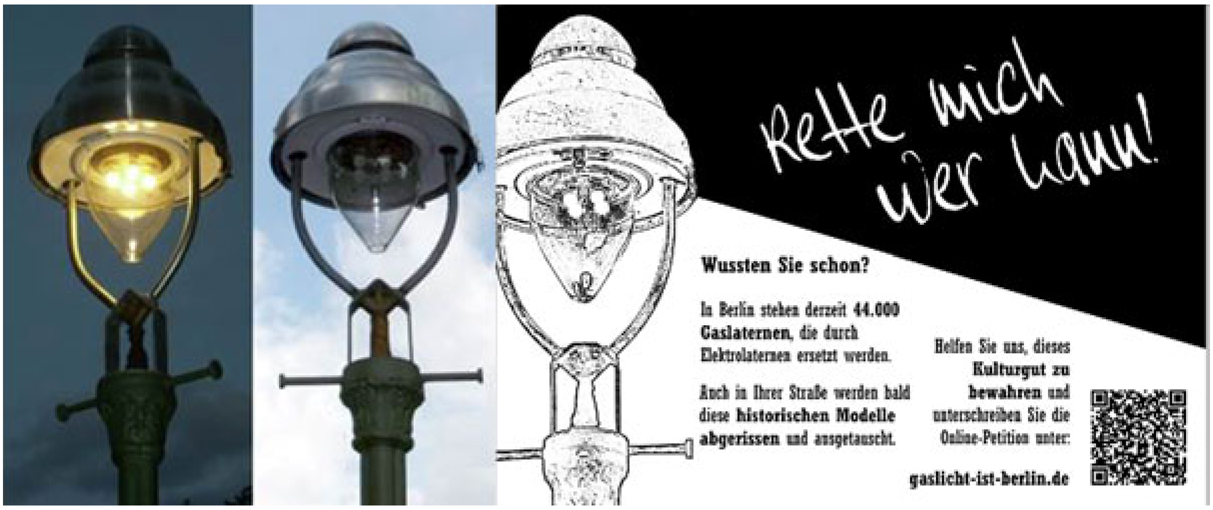

Figure 6-19: Gas pole-top luminaires © and a pro-gaslight protest flyer (CC).

The process: in search of a technological solution to a political conflict

In order of their appearance: gas lanterns and luminaires, urban energy supply systems, the Berlin Senate, gaslight amateurs, the Berlin light plan, private contractors, a fluorescent luminaire, lighting engineers at the Technical University Berlin (TUB), a manufacturer's working group, an LED gaslight imitation, the press, monument protectionists, zoning plans, an online petition, iron-cast pillars, LED replacements in Kreuzberg, a regeneration project in Neukölln.

In 2011, the Berlin light plan suggests that LED technology could replace around 30,000 so-called pole-top gas lanterns *(Gas-Aufsatzleuchten)*. It is stated that the new technology is still too expensive for a large-scale refurbishment (SenStadtUm, 2011). At the same time, it is pointed out that first tests and single replacements show that LEDs can imitate the beloved luminaires and their warm-white light very well. The developments that led to this new situation can be summarised as follows.

First, LED technology developed and became mature enough for public lighting while Berlin was discussing the electrification plans. During an expert meeting in autumn 2008, the head of public lighting presented his gaslight problem to lighting engineers and manufacturers and announced that the Senate was willing to invest in an LED solution to the gaslight conflict. The programme 'innovative lighting' was launched and the TUB lighting engineers were commissioned to develop a prototype lantern that would mimic gaslight. In the project, they collaborated with a Berlin-based research institute which developed customised warm white LED modules in the form of gaslight sockets (Figure 6-20).

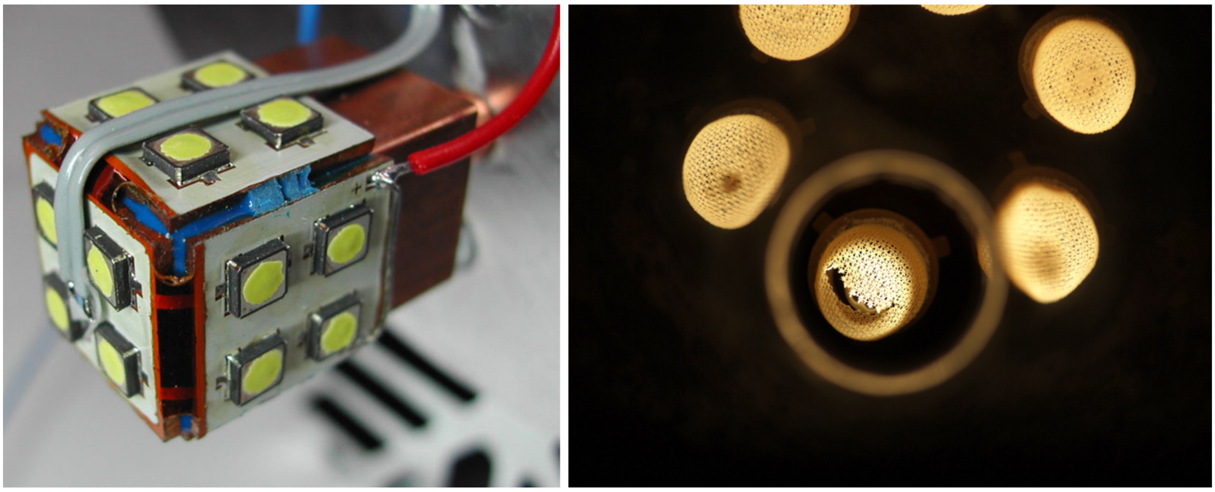

Figure 6-20: LED imitation of a gaslight socket and original (CC).

The development project was successful. The prototype was exhibited in public next to a gas-lit original at the TUB during the Berlin 'Long Night of Science'. The gas lantern and its imitation were indistinguishable. The head of the TUB lighting engineering department claimed that even the gaslight amateurs admitted that they could not see any difference.

But the convincing result did not surprise the lighting engineer. As he recalled (2013-02-06), he had initially thought that the Senate was wasting money. From a technological point of view, it had been obvious that LEDs could imitate gaslight. But the TUB professor, who was new in Berlin, soon understood why SenStadtUm had commissioned and needed the project. When he noticed the great public interest in the LED prototype and the political dimension of the gaslight issue he concluded that the money had probably been well invested after all (TUB lighting engineer, 2013-02-06). Retrospectively, he thinks that the public presentation of their perfect but very expensive LED-imitation of a gas luminaire influenced the political decision making process (ibid).

Almost simultaneously, local manufacturers launched a co-development project to provide the Berlin with a commercial LED solution (Abgeordnetenhaus Berlin, 2011-06-23, 2011-09-28). A medium-sized Berlin-based luminaire manufacturer developed the luminaire head with LED-module and optics together with an installing firm and a pole manufacturer with a special expertise in gaslights. The alliance co-developed a less perfect but cheaper LED-imitation.[333] SenStadtUm began to replace single historic gaslight luminaires with LEDs (Figure 6-21).

However, indistinguishable or not, the gaslight amateurs protested against the plans to destroy the world's largest remaining gas-lit ensemble. When the demolition of gas alignment luminaires started in June 2012 (NSR, 2012-04-25), the pro gaslight movement gained strength. The cold-white light of *Jessica*, the fluorescent replacement luminaire, stood in stark contrast to the warm white gaslight. In public debates, citizens complained and asked why SenStadtUm had not used LED technology here, too (NSR, 2012-08-21). Fact is that LED had not been mature enough when the luminaires were purchased. Meanwhile, the *Jessica* product line is also produced in an LED version (NSR, 2010-09-21).

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[333] Later, one of the partners developed a luminaire without the others, which is the one installed in Falckensteinstraße.

Figure 6-21: Saalestraße under construction: new 'historic' LED lanterns versus old gaslight (CC).

The pro-gaslight coalition organised panel discussions, a petition addressing the Ruling Mayor of Berlin, and sit-ins on construction sites to block the replacement process. A city-wide demonstration in front of the Charlottenburg town hall was organised for November 17th.

In this situation, the Senate Administration took action. The week before the political demonstration in Charlottenburg, it hurriedly mounted the LED luminaires onto the existing iron-cast poles in Kreuzberg and invited the local media to a press conference. In a telephone conversation, a SenStadtUm employee explained: 'We wanted to offer a different perspective. The people are confused. They'll read what's in the papers and believe every word' (NSR, 2012-11-14b, my translation).[334]

[334] OV: *„Wir wollten etwas dagegensetzen […] Die Leute sind doch verunsichert. Die lesen dann, was in der Zeitung steht und glauben das"* (NSR 2012-11-14).

Figure 6-22: New LEDs (left) versus old gas lanterns (right) in Falckensteinstraße ©.

On November 16th, the night before the pro-gaslight demonstration, journalists and camera teams met with SenStadtUm employees, the industrial project partners and the Berlin State Secretary who is in charge of the civil engineering department. Without being invited to the press meeting, some of the gaslight amateurs attended the event in order to ask the political decision makers critical and hopefully unpleasant questions in front of the media which they had prepared in their previous meeting (NSR, 2012-11-14a). They also handed the journalists their own press kit. The Senate Administration distributed one, too.

The installation was designed for the direct comparison of gas and LED lighting. Five LED lanterns were installed opposite a row of original pole-top gas lanterns on the other side of the residential street. The direct confrontation facilitated the evaluation. Indeed, the light colour, light distribution and shape of the luminaires are almost identical. In addition to that, SenStadtUm and the luminaire manufacturer also presented a brand-new innovative detail.

In contrast to previous LED replacements, the historic iron-cast pillars had been preserved this time, thanks to a new installation technique. The so-called bundle pillar masts *(Bündelpfeilermaste)* play a role in the gaslight conflict: Beautiful as they are, SenStadtUm wanted to preserve them. Yet the pillars also serve as gas pipes and have therefore no opening for placing the electrical cables and distribution box for the electric luminaire inside them. The gaslight amateurs criticised that the replacement of the old and solid cast-iron masts by new aluminium poles contradicted the Senate's climate political claims and was not considered in the municipal energy efficiency calculations. They called for a life-cycle analysis that would account not only for the energy consumption of the running luminaires but also for the energy consumed for destroying and reproducing the light poles and installation work. Against this backdrop, the new technique presented in Falckensteinstraße created new facts in the form of a process innovation that devalorised the gaslight amateurs' cradle-to-grave-argument. During the site visit, the manufacturer explained and showed how he cut the pillars open with a water jet beam in order to integrate the electric cables in the old pole.

The Senate's counter manoeuvre on the evening before the gaslight protest proved successful despite the gaslight amateurs' efforts to raise critical questions. The visible evidence was striking. The journalists did not see a significant difference between the LED and gas lanterns. In addition to that, the Berlin State Secretary responded to their questions about the costs of the refurbishment and gave them some fictive figures. The amount of money he named was far too low when talking about all the installation and underground work that needs to be done to replace a gaslight with an LED lantern. However, since neither the journalists nor the State Secretary clarified what part of the replacement costs they actually meant, the figure was not questioned during the event.

The press site visit was not the only time when Falckensteinstraße was used for displaying the technological solution to the political problem. In March 2013, the civil engineering department invited their colleagues from the urban planning and monument preservation departments in order to present their innovative method of saving the iron-cast pillars (NSR, 2013-03-12). From a preservationist' point of view, saving the 19th century pillars, which are only visible during the day, is at least as relevant as the warm light colour and light distribution. Again, the site visit was meant to provide visible evidence that the engineers' efficiency goals were compatible with the preservation of the day- and night-time urban image of Berlin, thanks to the innovation.

Invisibilising the technological transition

In contrast to Leibnizstraße, the public presentation of Falckensteinstraße was well rehearsed and the culmination of a series of previous tests and experiences including test sites like Saalestraße. Paradoxically, the development of an LED imitation of the gas pole-top lantern and its public presentation can be considered as an attempt by the actors of the urban public lighting network SenStadtUm to *re-invisibilise* their work after it had become a highly visible and politicised issue.

The visibilisation of the gas lighting infrastructures is a result of earlier and interrelated technical and social processes. On the one hand, the gaslights were visibilised due to their frequent technological failure. No technology is more visible than broken technology (see 2.3.1.). On the other hand, its public visibility is the result of political debates and the gaslight amateurs' efforts in raising attention for Berlin's unique immaterial cultural heritage and its 'barbaric' demolition. With their culturalisation of the Berlin gaslight infrastructures, the gaslight amateurs have opened the black box of urban public lighting. Their arguments were taken up by the media, especially in the cultural or comment section of local and national newspapers (Bernau, 2012-03-31; Martenstein, 2012-11-12; Zohlen, 2012-05-26).

But the gaslight amateurs not only revalued the outdated infrastructure as a cultural heritage. They also questioned the facts and figures which the Berlin Senate provided in order to justify the refurbishment project. In online comments the amateurs contested the experts' claims, including the key argument that the electrification would reduce Berlin's carbon footprint.[335] They also suggested that the gas lighting infrastructures had been purposefully neglected and could be operated much more efficiently if they were properly maintained. It is difficult to close 'Pandora's black box' once it has been opened (cf. Latour, 1987). As we have learned from sociologists of science (see 2.2.3) it is almost impossible for laypersons, and difficult for experts, to know 'the truth' when allegedly scientific or objective arguments are contested with counter arguments or discredited in public.

[335] For instance, they questioned the way in which the experts calculated and equated the consumption of gas as a primary energy and electricity, which needs to be produced by transforming primary energy like gas or, even worse, coal into electric power.

In this situation, SenStadtUm seems to have found a strategy to counter the amateurs' argument in public.[336] While the almost perfect resemblance between the LED and gas lanterns was obvious, the amateurs' questions were technical, detailed and more suitable for expert debates than media coverage. Last but not least, the Senate Administration used the occasion of the site visit to publically announce the conversion of 700 gas pole-top lanterns to LED light co-funded by the Federal Ministry for the Environment.

6.2.3 Altonaer Straße – advertising a typical LED retrofit solution

The LED luminaires in Altonaer Straße were installed only temporarily for a sampling event. Compared to the previous five case studies, the project thus presents a special case, in the course of which the LED product developers played a more important role than the municipal actors. In conceptual terms, it therefore qualifies as a *technology performance*.

The international manufacturer and a Berlin lighting designer presented their collaboratively developed new LED design on a rainy evening in May 2013. Six LED luminaire heads illuminated the wide street, three on each side, from a height of 10 meters. The audience consisted of SenStadtUm employees—members of the SenStadtUm public lighting team, the lighting expert from the urban design unit—the head of the Berlin light managing team and three participant observers—two social scientists from the Loss of the Night research cluster and me. The product presentation in front of the potential municipal clients was well-prepared and the luminaires' innovative features well received by the urban actors.

From the municipal perspective, the sampling event formed part of SenStadtUm's preparation for an important strategic technological decision. Linear street luminaires on curved poles *(Langfeldleuchte)* are widespread and typical for main streets in West Berlin. But they are also old and due to be replaced. In November 2012, SenStadtUm therefore actively started looking for a suitable retrofit solution. LED luminaires were considered as well as conventional light sources. The LED product line presented in Altonaer Straße was developed in response to this demand in Berlin and elsewhere for a retrofit solution. The Berlin technology performance in Altonaer Straße was a stage in the marketing of the new LED luminaire.

[336] The gaslight amateurs visibilisation work is also undermined by the ongoing dismantling of gas alignment luminaires in Charlottenburg and the installation of the fluorescent luminaire Jessica. The destruction of the contiguous ensemble of different historic and modern gaslight luminaires disrupts the consistency and threatens the authenticity of the amateurs' informative gaslight bus tours through the night-time streets of Charlottenburg.

Data: participant observation, interviews and context information

I first learned about the LED luminaire in Altonaer Straße during Light + Building 2012 where it was presented in the exhibition area of an international lighting manufacturer as part of the company's co-development programme (NSR, 2012-04-17). The product presentation in Altonaer Straße took place more than a year later (NSR, 2013-05-31). The product was presented with a reference to Berlin. The relation to the city also manifested itself through the involvement of a local lighting design office, where I conducted interviews with the lighting designer in chief and the product developer (lighting designer, 2013-02-15; product designer, 2013-08-22; NSR, 2012-11-14).

Information about the design process and the collaboration between the international manufacturer and the lighting design office was available online in the form of the manufacturer's PR (manufacturer, 2012-08-21).

Figure 6-23: Presentation of a new LED luminaire in Altonaer Straße on a rainy evening (CC).

Context information about the manufacturer's product development and administrative decision-making process in Berlin stems from my visits to the company's European lighting labs, demonstration and production sites close to Lyon (NSR, 2012-01-12) and informal conversations with the manufacturer's Berlin sales personnel and the SenStadtUm personnel (NSR, 2012-10-24, 2012-11-14b). A previous sampling event for similar products (NSR, 2012-11-27) allowed me to compare the technological performance in Altonaer Straße with the other situation which formed part of a standard product selection process.

Figure 6-24: An arch-like installation (SenStadtUm, 2011, p.54).

The situation: A forseeable public demand and a retrofit solution

In West Berlin, main streets are commonly flanked and lit by the above-mentioned slender linear luminaires on long curved poles. They were installed from the 1950s onwards and are equipped with fluorescent tubes. As outlined above, the light plan generally supports the preservation of typical luminaire types in order to safeguard the city's familiar urban image. The architect who is responsible for light questions within the SenStadtUm 'likes' how the neutral white lights on the curved poles create an arch-like perspectival impression when looking down a street (NSR, 2012-11-27).

Yet, the maintenance of the 40,000 outdated luminaires proved more and more difficult. In the absence of a suitable retrofit solution, the public lighting unit had the old luminaires repaired and furbished individually (NSR, 2012-11-27). To bring down the high maintenance costs and to improve the efficiency, it was laid out in the light plan that the poles should be preserved and the luminaire heads replaced with 'state-of-the-art technology' but similar-looking retrofit products *('typenähnlichen Ersatz')*, 'especially in most of the main streets and also selected wider connecting streets' where they contribute to the 'typical look' of the quarters

(SenStadtUm 2011, p.54, see Figure 6-24).[337] The light plan thus gave luminaire manufacturers a clear idea of what kind of product was needed in Berlin.

For manufacturers, the gradual replacement of 40,000 luminaires presented an attractive sales opportunity. Like other luminaire manufacturers, the international lighting company behind the retrofit product presented in Altonaer Straße provided an answer to the demand and offered SenStadtUm an LED solution. But the old linear luminaire in question is widespread not only in Berlin but also in other places and European countries.

Therefore, the LED product line was designed with a customisable light distribution and is thus flexible enough to also meet the demand of the wider European lighting market. Thanks to interchangeable LED modules and optics the luminaires can meet the requirements of smaller streets and wider roads, of large and short pole distances, high and low light points. To meet the challenge of the fast technological development, the product line was equipped with the manufacturer's standardised LED-driver-modules.

The product was developed in the course of a 'co-development' programme which focuses particularly on urban public lighting and seems to function as both a call for partners and a marketing story. On the manufacturer's website the programme is presented in the 'future of light' category under the heading 'lighting trends', with the express aim to work together with cities, energy suppliers and lighting designers in order to benefit from their knowledge of the urban situation. The manufacturer promotes its 'dedicated application and product development teams' on his website and invites new collaborators to make use of their support. Public lighting is described as a task that exceeds purely functional needs and is part of a city's aesthetic appearance, its ambiance and its urban landscape. The collaboration is presented as a response to 'a clear wish of citizens and local decision makers to return the city to its citizens and bring back the quality of city life.' According to the programme description, the 'co-development' is intended to help 'improve the livability for inhabitants and enhance cities' identities with light' by creating 'meaningful lighting solutions.'

The present collaboration was initiated in 2010 by the lighting designer and the manufacturer. The lighting designers had an intimate knowledge of the Berlin situation. The design office

[337] OV: *„Eine Erhaltung des typischen Erscheinungsbildes der Langfeldleuchten ist jedoch vor allem in den meisten übergeordneten Straßen wie auch in ausgewählten breiteren Erschließungsstraßen [sofern sie dort zur Quartierstypik beitragen] geboten. Deshalb empfiehlt es sich, typenähnliche Nachfolgeleuchten auf dem jeweils aktuellen Stand der Technik entwickeln zu lassen"* (SenStadtUm, 2011, p. 54).

had already planned the lighting for several prestigious Berlin regeneration projects and is known for its good relations with the SenStadtUm urban design unit (NSR & Toschka, 2013-05-29). As part of the Berlin light panel, the chief designer also actively assisted in the development of the Berlin light plan (2011).

A German energy supplier acted as a consultant and advised the developers from the installer's point of view, i.e., with regard to practical questions like the length of cables, the use of screws and maintenance issues (product designer, 2013-08-22). According to the product designs, the urban co-devlopment programme was only 'inspired by' the Berlin situation (2012-04-17, 2013-05-31). While in other cases, municipal actors were part of the design teams, SenStadtUm was aware of the project but not actively involved in the design process.

The Process: the right light at the right place

In order of their appearance: 40,000 linear street luminaires, the Berlin light plan, an international lighting manufacturer, Berlin lighting design office, a German energy supplier, SenStadtUm, a new LED luminaire design, a main street in Berlin Wedding, a main street in Berlin Tiergarten, the Berlin light manager.

The product line was first presented in April 2012 during the international light fair Light+Building in the manufacturer's exhibition area together with other collaboration projects (NSR, 2012-04-17). The 'co-development' had been initiated two years earlier in the same place, during L+B 2010. At the time, SenStadtUm's intention to replace Berlin's old linear luminaires had already been known to the lighting designer who assisted the city as an expert in the development of the light plan, as described above. According to the actors involved in the design process, their collaboration was a success.

The Berlin lighting designers speak very highly of the manufacturers' product co-development team praising their technical expertise. The product designer suggests that both sides have learned in the process (2013-08-22). The manufacturer benefited from the designers' attention for usability issues. The designers were asked to think on an industrial production scale. What mattered was not only design and its performance but also its mass production. This included material issues, like the avoidance of sharp edges, which are the parts of a product that are most vulnerable and break (NSR, 2013-05-31), or the question of industrial reproducibility, for instance whether the fabrication of the new product required new and expensive production tools (product designer, 2013-08-22). The manufacturer kept close track of production costs. Some design ideas were discarded in favour of cheaper solutions.

In the manufacturer's PR video clip, the lighting designer in chief describes the complementary competences of both parties:

> 'A co-development between a manufacturer and a lighting designer can be very fruitful because we are looking from two different perspectives. The lighting manufacturer has his high skills in the production process and in the sales knowledge. We, on the other hand, as independent lighting designers, are interested in the project. So we want a product which is very adaptable and flexible […], looks good and is very functional. When these two perspectives […] come together we end up with a product for the customer.' (manufacturer, 2012-08-21)[338]

During the development of the new product line LED technology kept on developing rapidly. In the course of the design process, the product developers replaced the LED system inside the new luminaire with an updated version of its standardised LED module which was more efficient but had the exact same size and the same light distribution. The shape of the luminaire was therefore defined by the size of the LED module.[339]

The module was also combined with the electronic LED driver—a conscious and innovative design decision and a technological challenge, too. Both components produce heat and require thermal management and are therefore usually kept apart in order to ensure that the diodes do not become too hot. In this case, the product developers reasoned that the electronic drivers will not outlive the LEDs, which have an expected life span of 50,000 to 60,000 hours.[340] 'It does not make sense to replace the LED module without replacing the driver too', explained the lighting designer. They therefore integrated the electronic ballast in the LEDs module in order to facilitate its maintenance. Both components can be replaced in one simple step *('mit einem Handgriff')* (NSR, 2013-05-31).

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[338] In the same PR clip, his partner describes the collaboration between the heterogeneous project teams as 'the best basis for innovation and for a product which integrates the requirements of a modern city' .

[339] The developers benefited from the international manufacturer's standardisation efforts. The company itself owns a firm that produces diodes which makes it easier to manage the production chain from LED package to the LED luminaire (see 4.1.1).

[340] Real-life experiences showed that drivers fail before the LEDs.

Figure 6-25: New LED light on old poles and photo from the manufacturer's website (CC).

Technological considerations also allowed the developers to save costs. Based on the assumption that the luminaires only need to be maintained and opened once or twice in their life time the developers opted for a cheap technical solution for opening and fastening the luminaire. While other luminaires have quick-releases and can be opened and fastened without tools, installers need a screwdriver to open the luminaires of the present product line (product designer, 2013-08-22).

A few months after the product display during L+B 2012 the first luminaires from the new product line were installed in a German town on 7.50-meter-high poles. Simultaneously, the developers prepared for a sampling event in Berlin. Late in 2012, SenStadtUm asked manufacturers to present their retrofit solutions for the outdated street luminaires on curved poles. On a November evening, a first sampling took place in Afrikanische Straße in Berlin Wedding (NSR, 2012-11-27). Different LED and fluorescent luminaires by different manufacturers were temporarily installed next to each other in Afrikanische Straße and illuminated the wide street in slightly different colours and with different light distributions. Although SenStadtUm had also invited the developers of the new LED luminaire to present their collaborative design in Afrikanische Straße, they chose not to.

Figure 6-26: A new product staged in front of the Berlin Victory Column ©.

According to the manufacturer, the street in Wedding was not suitable to demonstrate the innovative LED luminaire to its full effect (NSR, 2012-11-14b). In Afrikanische Straße, the poles are only 7.50 meters high. What the developers had in mind was a presentation on 10 meter high poles. After they had already installed the 7.50 meters luminaire elsewhere, they now looked for an opportunity to show that the new product line offered high-quality customisable solutions for all standard pole heights, including 10 meter high poles, and street types.[341] In addition to that, the lighting designers also reasoned that the slender luminaire heads would look better on longer poles and thus better meet SenStadtUm's urban design expectation (NSR, 2012-11-14; product designer, 2013-08-22). The selection of a suitable street was thus paramount for the effective product presentation as will be outlined in more detail below (7.1.2).

During the first sampling event in Afrikanische Straße, manufacturers had provided the luminaires but were not even present. In Altonaer Straße the luminaire developers—lighting designers and the manufacturer's staff were in the majority and had prepared the event

[341] On the manufacturer's website, the product line is advertised as 'new light on old poles'. It is pointed out that the key concept was to create a modular tool for pole heights from 3.5 meters to 10 meters.

thoroughly. While it was getting dark, the chief lighting designer gave a detailed account of the product and its innovative features, like the easily replaceable modular system with integrated LED driver, its customised light distribution and its efficiency. One of the product designers took pictures with the LED luminaires in front of the illuminated Berlin Victory Column in the twilight of the so-called 'blue hour' when there is still enough daylight to see the luminaires. When it was fully dark, the manufacturer's team started a digitally controlled dimming show in the course of which the LEDs were turned up and down to show the full scope of their light output.

The temporary installations of newly designed LED luminaires can thus be considered a technology performance in front of a selected expert audience of potential clients. The product was staged as the perfect retrofit solution to Berlin's large-scale refurbishment problem and designed to have an impact on the municipal public procurement decision for the projected replacement of the 40,000 old linear street luminaires.

An overflowing technological performance and marketing 'truth-spot'

The temporary installation in Altonaer Straße was a well-staged product performance at the right time, at the right place and in front of the right people. This does not imply that Berlin will buy the luminaires. It does mean though that the performance allowed the luminaire developers to impress their audience and to produce two forms of evidence, one situated and Berlin-related, the other giving the impression of generalisability. In the first respect, product performance provided visual evidence that the luminaires were suitable for Berlin. In his eloquent product explanation, the lighting designer explicitly addressed city-related issues, for instance the possibility of dimming the energy and brightness of the luminaires to the desired level.

In addition to this, all visual evidence was perfectly presented. The visitors arrived at the perfect time when there was still enough daylight to see the new luminaires in 10 meters height—and not only their light. The lighting designer's speech was just long enough to make time pass and let night fall. At the right moment, the manufacturers started the dimming show, when it was dark enough to appreciate the smooth changes in light levels. Only the rainy weather slightly impaired the otherwise perfect product performance. On the rainy evening, the wet surfaces reflected the light and made it impossible to admire the supposedly homogeneous light distribution on the street.

In addition to this visible and Berlin-related evidence, the technology performance also produced take-away imagery for later product presentations on websites or catalogues. By installing and photographing their LED luminaires in front of the Berlin Victory Column, the luminaire developers also created visual proof that their product line was ready for use—even the LED luminaires for larger roads on 10-meter-high light poles. In this respect, Berlin can be considered as a truth-spot for producing evidence and for marketing the new product line elsewhere. After all, the 'Berlin co-development' was never developed for the German capital only. The new luminaires are designed for industrial mass production and meet all light technological and safety standards required for lighting European streets. According to a product manager, the manufacturer's marketing strategy particularly targets the so-called DACH region (Germany, Austria and Swiss) where the Berlin linear luminaires are also widely used. Thus, the event was designed to overflow beyond the immediate performance situation and the Berlin circle of spectators. In the aftermath of the technology performance, SenStadtUm had the luminaires removed.

6.3 Summary and outlook: Commonalities and differences

As we have seen, the above-described cases are very different in terms of the actors and things involved. In fact, even the newly introduced LED fixtures vary considerably. In order to prevent hasty conclusions and wrong generalisations, I will briefly outline their commonalities and differences before comparing and contrasting the cases.

The cases have in common that they all qualify as *early public LED installations*. They qualify as *early* from the municipal perspective since the municipal project developers were not yet familiar with the new technology and had little or no previous real-life experiences. They qualify as public because citizens and interested publics, including protesters, had open access to the installation sites, as the press event in Falckensteinstraße nicely demonstrated. They are *installations* as the innovation was put into place to become part of the urban public lighting networks, including their maintenance routines and infrastructures, as the case of the Lyon test streets illustrated.

Apart from this common denominator however, the projects varied considerably with regard to their socio-material situations. Two categories[342] seemed particularly relevant. First, the six cases differ in terms of *heterogeneity* and, second, with regard to the *innovation* that was introduced. The heterogeneity of the actors involved in the six projects can be depicted as follows:

	Place Bellecour	Rue Thénard / de l'Oiseau Blanc	Montée du Boulevard	Leibnizstraße	Falckensteinstraße	Altonaer Straße
citizens				(survey)		
local media						
lighting amateurs						
local politicians						
monument preservationists						
landscape designers						
municipal urban designers						
lighting designers						(product design)
university lighting engineers						
private light managers						
installers						
municipal public lighting units						
luminaire manufacturers						

Professional background	lighting or lighting technology	lighting or urban design architecture	not light-related

Table 6-1: The six projects and their heterogeneous actors.

Heterogeneity refers to the involvement of different actors and also to their different views or professional visions and expertise. All these human actors engage with material worlds, mobilise resources and have their objects and objectives, for instance the preservation of gaslights or the introduction of intelligent LED systems. While in the case of the Lyon test streets only the 'usual suspects' of the public lighting networks were involved, projects like Place Bellecour and Falckensteinstraße also interested monument preservationists or even citizens. In Montée du Boulevard, Altonaer Straße and Leibnizstraße, the projects were

[342] These *categories* describe analytically relevant features of projects in a qualitative way. They are the result of my grounded situational analyses (see chapter 3) and should not be confused with variables as they do not describe causal relationships but relations.

carried out and observed by the cities' extended expert public lighting networks, which includes lighting designers and scientists.

In terms of heterogeneity the cases can be ordered as follows: As the table shows, the projects with the least heterogeneous relevant actors were the test sites Rue Thénard and Rue de l'Oiseau Blanc. The municipal planners carried out the project together with the manufacturer. The DEP project planners represented their interests or perspectives.

The sampling event in Altonaer Straße comes next on the heterogeneity scale. It involved the Berlin public lighting team, the manufacturer and Berlin-based lighting designers who were actively involved *as co-developers* of the LED luminaire. A municipal urban designer and the head of the private light management team were present as observers during the product presentation.

In Montée du Boulevard the municipal planners collaborated with lighting designers and the manufacturer. The municipal maintenance department, which presents the Lyon equivalent to the Berlin light manager, was not actively involved in the planning process but represented by the DEP planners. The project was the only case in which an installation firm played an *active* part, namely when it came to fixing the LED cable in the medieval sloping terrain. Furthermore, the lighting designers gave the local users of the stairway a voice by observing and addressing their activities in their design.

In the particular case of Leibnizstraße, the project was planned by the manufacturer and the municipal civil engineers with the support of the TUB lighting technology department. The Senate had to approve the pilot project and its funding. The private light manager was not involved, nor any lighting designers. The social scientists and urban planners from the Loss of the Night research cluster joined the project later and explored the social acceptance of the project in their resident survey. Again the residents were only represented, hence passively involved.

As a large and long-term urban regeneration project, the Place Bellecour case involved an even more heterogeneous set of actors, including monument preservationists and politicians in addition to 'the usual suspects' of public lighting. Local residents were considered in the design as the square was configured with regard to its symbolic function and to the pedestrians' and cyclists' safety needs. Yet they did not change the course of events.

The installation in Falckensteinstraße presents the most heterogeneous case. It is also a direct result of heterogeneous conflicting interests. It sticks out as the only case in which interested and engaged citizens played an active role in the planning process through their protest and public critique. In addition to the gaslight amateurs, SenStadtUm also enrolled municipal monument preservationists, the urban design department, the private light manager and Berlin-based manufacturers in the project.

As we have seen in chapter 2, the heterogeneity of actors and audiences should theoretically have an effect on the testing and showing of innovation. The more heterogeneous the observers are, the greater the chance or risk of controversies and diverging evidence production. The literature on public experiments suggests that such negative effects can be prevented through careful preparation and rehearsal. How these theoretical assumptions relate to my case studies, and the question of *how LED lights were introduced* will be explored in the next section.

In terms of technological *innovation*, the technology installed ranged from off-the-shelf standard luminaires (Rue Thénard and Rue de l'Oiseau Blanc), to innovative but already mass-produced LED systems (Leibnizstraße, Montée du Boulevard), to customised and purpose-built mass-produced retrofit solutions (Falckensteinstraße and Altonaer Straße), to special designs (Place Bellecour) as outlined above (see Table 3-1).

In theory, I have already criticised innovation perspectives that give the impression of a goal-oriented or, even more misleading, a linear innovation process. In chapter 2 I questioned the conceptualization of technology trials and demonstration as a last stage in the innovation process and starting point for diffusion. My empirical observations support this critique in two respects. First, the six case studies show that the absolute newness of LED products was not decisive for the municipal testing and showing activities. The Lyon DEP planners also tested standard off-the-shelf products. The Berlin Senate tested and showed city-specific retrofit solutions, although the lighting engineers were already certain that LED technology could imitate gaslights. The question then is what municipal engineers actually tested, if not the newest untried products. Second, the case studies show that the adoption of LED luminaires led to adaptations and new challenges that created the need for technology trials and modifications in the diffusion stage. As I will outline in the next chapter, both findings support my thesis that innovation processes do not end with the installation of new products and that LED technology is modified in site-specific and city-specific ways.

7. Analysis and discussion

In chapters 4, 5 and 6, I have described the situations of early public LED installations from a global, urban and project-specific perspective. In this chapter, I will zoom out again while linking my findings to my theoretical concepts. I will first compare and contrast the six cases in order to understand their test-show trajectories. This will answer the question of *how* LED lighting was introduced (7.1). Afterwards, I will focus on the evidence and information that was produced in the course of the projects and argue that what was shown to project observers supports site-specific valorisations of the new light (7.2). The case comparison also reveals city-specific patterns that cannot be explained when comparing the projects. I will therefore 'scale up' and once again contrast the public lighting networks of Berlin and Lyon and their audiences (7.3). Most importantly, this comparison will reveal that LED lighting was not only differently tested and shown but also introduced in city-specific configurations.

7.1 Comparing installation processes: Test-show trajectories

In chapter 2, I argued that innovating in public involves testing and showing in front of heterogeneous audiences. In chapter 6, we saw that the actors indeed referred to their installation activities as tests, experiments or demonstrations. This was not mere rhetoric. All six LED projects involved instances of trial and error as well as public evidence production and technology performances in front of heterogeneous audiences. Yet the projects also showed different degrees of heterogeneity. In some cases, the actors and groups involved were very heterogeneous from the start, as in the case of Place Bellecour or Falckensteinstraße. In other cases, new actors became interested during the planning process, for instance the social scientists in the case of Leibnizstraße. In addition to that, in the course of their development the projects moved between the poles of testing and showing. In Montée du Boulevard, the Lyon DEP had no intention of seeking public attention but the manufacturer publicised the installation and showed it to clients. In the case of Leibnizstraße, the project was designed as a public demonstration with experimental elements but ended up as a public trial for its developers.

The following two illustrations Figure 7-1 and Table 7-1 integrate my empirical findings, as outlined in chapter 6.3 and Table 6-1, and my conceptual framework as outlined in 2.3.2 and

Figure 2-1. They also raises questions, which will be addressed in this chapter. But first I will briefly explicate my categorisations.

Figure 7-1 illustrates how the projects developed between the poles of testing and showing and how these trajectories relate to their heterogeneous actors and observers.

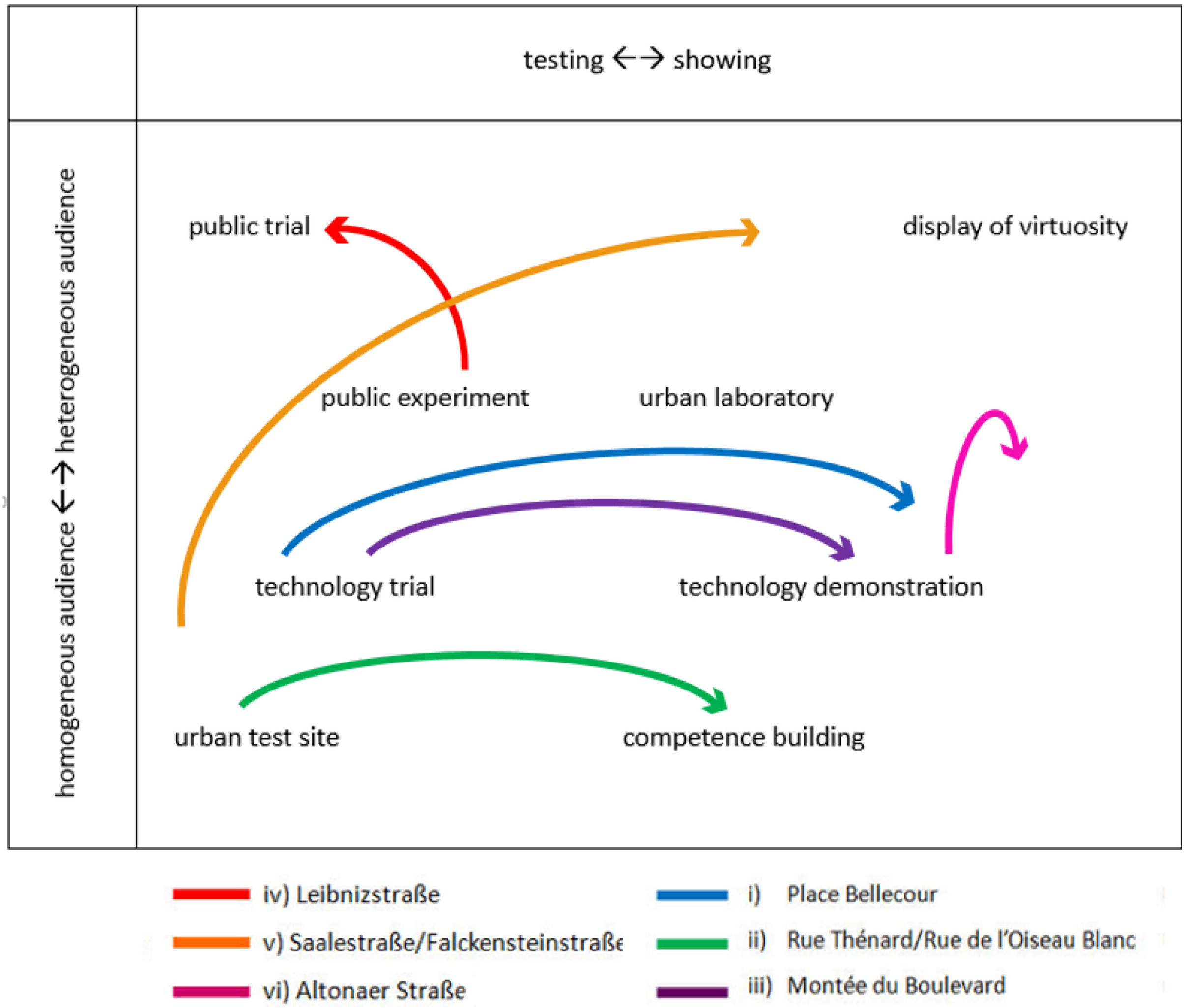

Figure 7-1: Matrix showing test-show trajectories in front of heterogeneous audiences.

The graphic illustrates my categorisation of the cases in terms of testing and showing, from *urban test sites* to *displays of virtuosity*. As sketched out in my case introductions, I consider Place Bellecour and Montée du Boulevard to be *technology trials* that turned into *technology demonstrations*, although the heterogeneity of actors and observers was greater in the first case (see Table 6-1), which is why Place Bellecour is higher up on the heterogeneity scale. In contrast, Rue Thénard and Rue de l'Oiseau Blanc can be characterised as *urban test sites,* with very low public appeal and a long-term goal of building intra-organisational *competence*.

Similarly, the project in Falckensteinstraße was first developed in rather ‘private’ settings, unnoticed by gaslight amateurs, in streets in Neukölln and Kreuzberg. As such, they functioned as *urban test sites* for the ‘*display of virtuosity*’ in Falckenstraße in front of the local media. The special case of Altonaer Straße, where LED luminaires were only installed temporarily, can be described as an ephemeral *technology demonstration* or just a *performance*. Finally, the *public experiment* in Leibnizstraße, the only case with active scientific involvement, failed as an intended municipal *technology demonstration*. It was also challenging as a scientific *public experiment* and resulted in a *public trial* from the municipal perspective.

Table 7-1 is based on Table 6-1. It concerns the question of who became involved in the course of the projects and adds empirical depth to the notion of heterogeneous audiences.

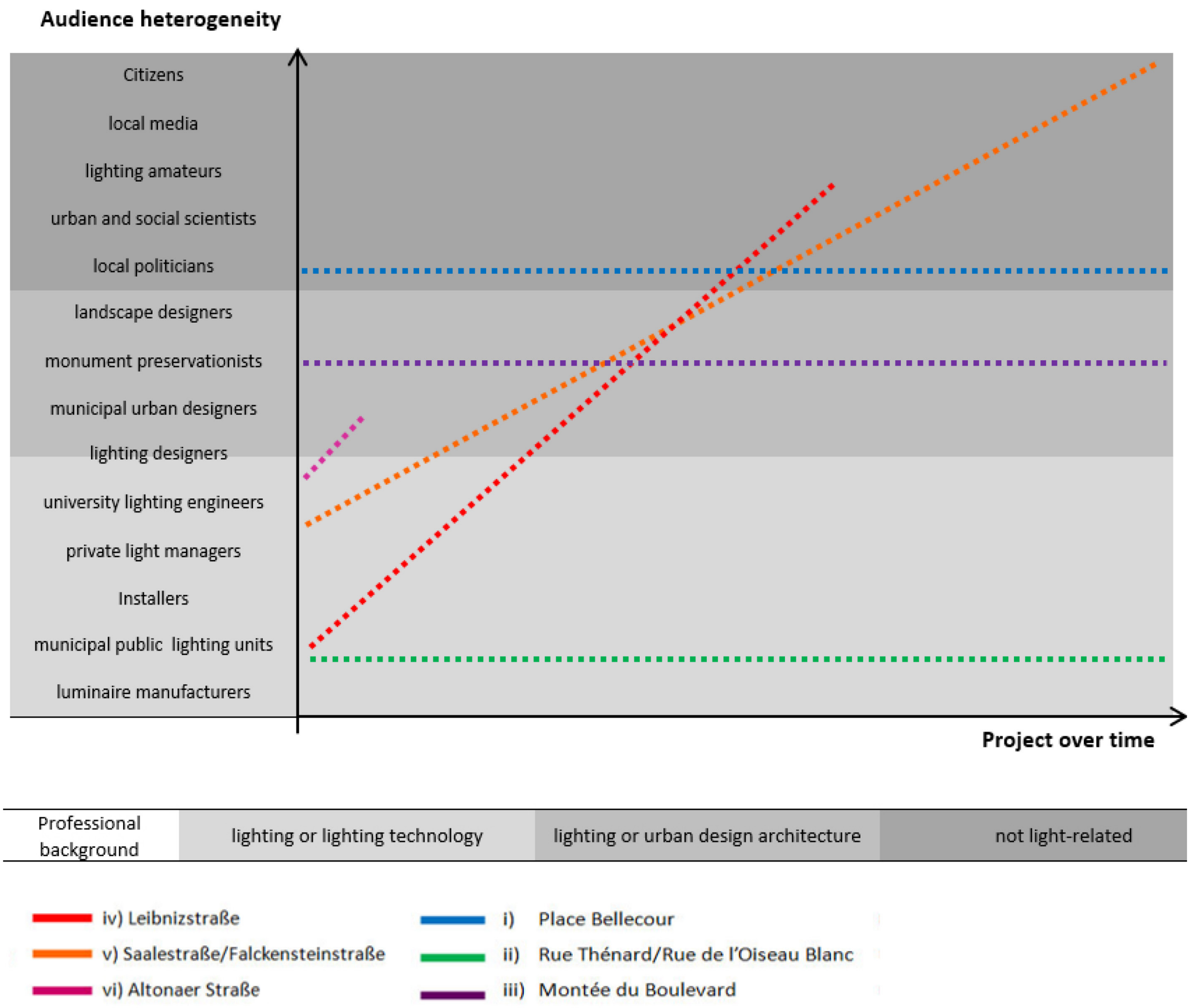

Table 7-1: The involvement of heterogeneous actor groups in the course of the six projects.

The trajectories in Figure 7-1 and development of involvement in Table 7-1 raise questions: Why did the promising public experiment in Berlin Leibnizstraße not result in the expected innovation showcase whereas the LED imitation in Falckensteinstraße became a municipal success, despite its more heterogeneous and much more critical audiences? How did the Place Bellecour team manage to develop a technology trial that more or less smoothly turned into a public technology demonstration and produced uncontested evidence in a planning situation that was publically exposed and politically delicate (it involved trees and a car park) and in front of heterogeneous audiences? How did the DEP keep the degree of public attention low so that they could test LED technology, gain experience and develop their competence quite *privately* in public streets? These questions can be addressed and answered in 'empirical ontological' or 'epistemological' terms.[343]

In the first respect (see 2.2.2), we can draw on the ANT innovation model, which suggests that spokespeople of innovation need to mobilise *all relevant actors and non-human entities* in order to be successful. Since lighting engineers, lighting designers, municipal public lighting services and lay observers including mass media and residents 'see' and engage differently in public light planning we can assume that the challenge of 'interessement' was greatest in the cases of Falckensteinstraße, Place Bellecour and then Leibnizstraße and Montée du Boulevard (Table 6-1 and Table 7-1).

In the second respect (see 2.2.3), showing innovation in public is risky. As Harry Collins (1988) argues, it is foolish to expect incontestable evidence and unanimous interpretations of facts to emerge from techno-scientific experiments that are performed in public in front of heterogeneous audiences, including the media and laypeople. From an epistemological point of view, it seems advisable to test new facts or artefacts in private and show them in controllable public situations after previous rehearsal. Both strategies appear problematic with respect to urban public spaces. Nevertheless, I observed such 'spatial attention management'. It was most apparent in the cases of the Lyon test streets and the commercial technology performance in Altonaer Straße.

[343] By 'epistemological' I mean not only scientific knowledge production but also other ways of knowing. By 'ontological' I mean pragmatist perspectives like ANT. In this respect, Noortje Marres differentiates between *theoretical* and *empirical ontology*. While the first is 'a theory of "what exists" […] Empirical ontology differs from theoretical ontology by proposing that the question of 'what the world is made up of' cannot be answered wholly in theory but is partly settled in practices that must be studied empirically' (Marres, 2013, p. 422).

The following discussion first draws on the ontological perspective, which highlights the pragmatic testing of relationships (7.1.1), and then addresses the epistemological problem of managing public attention in urban spaces and in front of heterogeneous audiences (7.1.2). I consider these approaches as complementary perspectives on the test-show trajectories.

7.1.1 Following the actors: First testing, then showing

As outlined in chapter 2, the 'art of interessement' lies in interesting and mobilising all relevant actors in a way that prevents 'dissidence', as Michel Callon puts it. In his 'Sociology of Translation' (1986b), Callon describes this network formation process as bilateral pragmatic tests and trials (cf. Dewey, 1958). Place Bellecour is exemplary in this respect.

As we have seen, the spokespeople for LED lighting were the lighting designers. In the course of a long planning process, they came to the conclusion that LED technology was mature enough and the best available means to illuminate the square homogeneously, which was the DEPs key objective, given that they wished to achieve energy efficiency. A Lyon-based LED and luminaire manufacturer, whom the lighting designer trusted, offered a 'very precise and avantgardist solution' (Lyon lighting designer, 2012-01-09). The manufacturer was the planners' first choice as it was the only LED developer to offer LED luminaires with an asymmetric light distribution that was perfectly suited for illuminating an exceptional space like the vast Place Bellecour. The product had already been commercially tested—it had already been in the manufacturer's 2008 catalogue.

Nevertheless, the proposed technological solution had to pass several trials before it was successfully installed. The lighting designers had to convince the professionally heterogeneous planning team, including monument preservationists and, of course, the DEP engineers. While the former were in favour of the symbolic crown-shaped design, the latter were reluctant to install a barely tested technology on Lyon's most prominent square. In this situation, the temporary mock-up technology trial of different luminaires, including LEDs, on *site,* was decisive. It provided the municipal lighting expert with visual and measurable evidence that the LED solution was unbeatable. Their commitment was reinforced by an 'interessement device', namely a 10-year-warranty on the products, which the DEP negotiated with the manufacturer. At this point, all members of the planning team were interested and the trials—mock-up and warranty—had stabilised their relationships. Yet to ensure the compatibility of the new light with the existing urban infrastructures and the familiar world, more *in vivo* trials were necessary.

The old electricity grid proved unreliable in terms of voltage. In order to rule out the destruction of the LED luminaires, the lighting designers installed a series of overvoltage protection devices. Second, the LED manufacturer guaranteed the colour temperature of the LED light[344] and the light distribution of the LED luminaires was carefully adapted to account for the vast size of the square. As a result, the light quality and levels met all expectations and undesired public attention was prevented. The lighting designers had already had a bad experience in this respect. When a previous installation of light projectors to illuminate the statue of Louis XIV in the centre of the square had also involuntarily illuminated some windows of surrounding houses, residents had complained about light nuisance.

Thanks to the experts' proactive testing and previous trying, the new lights on Place Bellecour *did not* turn into a public issue. Not even the dimming of the lights raised public concerns. Again, the DEP had previously tested social acceptance of reduced light levels during the EVALUM series. Thus, the long-established relationship between experts and lay audiences remained unquestioned. By making sure that the technology worked as expected and the visual comfort of those who crossed or lived next to the square was not compromised, the experts confirmed their role as representatives of lay beneficiaries of public lighting and their innovating in public did not turn into a public trial.

At the same time, the planners engaged politicians and lay audiences by presenting impressive energy savings. 12 LED luminaires with a connected load of 720 Watt each had replaced 18 old 3000 Watt luminaires (Lyon lighting designer, 2012-01-09). The dimming reduced the energy consumption of the new installation even further. The above-mentioned local TV station reported on the 'new LED luminaires' with the unambiguous message that 'millions of euros can be saved' and that LED light was 'more economic and ecological' (Tele Lyon Métropole, 2011-10-18). In addition to that, the 'small world of lighting' acknowledged the project as a successful LED demonstration (NSR, 2012-04-15). I conclude that the early public LED installation on Place Bellecour represents an exemplary case of a trajectory from testing to showing innovation.

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[344] Changes in colour temperature are one potential problem that can occur over the life time of LEDs—alongside with flickering and the degradation of light levels.

Comparing the cases, only Montée du Boulevard shows a similar pattern with a less heterogeneous set of actors and observers. Again lighting designers were the spokespeople for LED light. They attracted the DEP's interest by proposing a solution that illuminated the staircase more effectively and economically, decluttered the scenic view and was easier to operate for the DEP maintenance team. As on Place Bellecour, the compatibility of the LED fixtures was tested and checked in a number of site visits. The suspension of the luminaires was especially problematic and required the planning team's particular attention. The cable did not react well to the cold in its new natural environment and its fixation points threatened to damage the ancient walls of the Lyon ramparts. Accordingly, the planning team invited new 'allies': An installer placed the poles and the manufacturer found a new cable to replace the old one.

However, the compatibility of LED luminaires, cable, poles, staircases and ancient walls was not the only relationship on trial. In the course of the project, the municipal lighting engineers also tried their private project partners, especially the international manufacturing firm. They negotiated the price for the lighting equipment, asked for a different colour temperature and demanded better technological solutions. According to his colleagues, the DEP chief planner was quite demanding. The manufacturer accepted the challenge and was rewarded with a product improvement, the better cable, and a demonstration project that opened up the French market for the new product line. In contrast to Place Bellecour, the project was only shown to lighting professionals and the rather hidden wild-romantic staircase did not receive any wider media or political attention.

Finally, 'interessement' was no big problem in the course of the routine replacements in Rue Thénard and Rue de l'Oiseau Blanc. In these projects, the most relevant relationship on trial is the relationship between the DEP maintenance department and its new LED lights. It is still being tested. The interesting question of how public interests were kept out of the process will be addressed in the next section.

In contrast to the two Lyon examples, which had smooth trajectories from testing to showing, the Berlin cases show that public technology trials can also be less fortunate or more challenging. While the case of Leibnizstraße illustrates how the introduction of technological innovation can turn into a *public trial for the innovators*, the example of Falckensteinstraße presents a case in which the public lighting network was *already on trial*. In this situation the new technology offered a chance to re-establish working relationships within the urban public lighting network and with its wider public.

To start with Leibnizstraße, the first Berlin early public LED installation, represents an unfortunate attempt to test and show innovation in public. As outlined above, the spokespeople for LED lighting, this time the municipal public lighting unit, felt they were lagging behind and envisioned the project as an opportunity to gain experience with LEDs and catch up with the innovation process —'everybody talked about LEDs. And Berlin was the only city without LEDs.' While this is an exaggeration,[345] the statement reveals that the SenStadtUm engineers were not only driven by the goal of testing LED lighting but also wanted to *show* it. From the very beginning the installation was meant to become a *display* of their capacity to keep up with the technological innovation in their professional domain.

In order to demonstrate that Berlin was up-to-date in public lighting, SenStadtUm went for a digitally controllable, dimmable LED technology. Yet in contrast to the Lyon lighting designers, the Berlin municipal spokespeople for LEDs were less successful in establishing reliable relationships between the new technology and the existing public lighting network. The public presentation of the new installation was the first disappointment. The second occurred later when they were unable to exploit the innovative telemanagement system and dimming function of the installation due to calculation problems regarding the reduced energy consumption. As a result, the project did not attract special attention in the world of lighting, nor did it produce the kind of information or undisputable evidence, e.g. information about energy and cost savings, that is characteristic for technology demonstrations. Instead, it seems that SenStadtUm felt they had to justify the project and were themselves on trial.

Again, the interessement model is useful for revealing the problems in the installation process. I have identified four instances of incomplete enrolment: First, the SenStadtUm team acted as spokespeople for LED technology but relied on partners to perform that role. In the public procurement process the TUB lighting technology department helped them to identify the innovative products. The TUB engineers had their particular interest in the project as they wanted to use it as a field site for real-life measurements. Yet as we have seen, the street proved problematic as a field site due to car traffic and a great number of private illuminations

[345] It might be true that everybody talked about LEDs in 2009 but not 'every city' had already installed the new technology. However, if the professional conferences on street lighting were the places where SenStadtUm engineers got their ideas from, they must have heard the LED testimonies of exactly those colleagues who had been invited as speakers because they had LED lights installed and could tell their peers about their experiences.

from shop windows that made it difficult to produce scientifically valid photometric results *in vivo*. It seems that SenStadtUm's choice of a street, which was related to their wish to *present* LED lighting in the City West area, was not the best choice for the public experiment.

Second, SenStadtUm worked with a LED manufacturer that, according to its clients, soon 'lost its interest' in the already outdated LED system installed in Leibnizstraße (NSR, 2013-07-31). Their relationship had already proven problematic before. On the inauguration night, the manufacturers' project manager switched on the over-dimensioned LED lights on full power as the municipal client had not ordered them to do otherwise. As a result, the audience did not applaud but complained about glare. I assume that the manufacturer could have anticipated the problem. Apparently, the planners had neither tested nor discussed the problem with their inexperienced client.

Third, the relationship between SenStadtUm and its private light manager was tested too late. The public-private partnership with the new light manager started in October 2011, a few weeks before the completion of the project. The manager had not been involved in the planning and then showed, according to SenStadtUm, little interest in operating the innovative telemanagement system.

Fourth, SenStadtUm could not engage their private energy supplier, which belongs to the same company as the light manager. EU regulations require that energy supplies are measured with officially calibrated metering devices. But these were not integrated in the dimmable LED system. Accordingly, the private energy supplying firm refused to account for the energy reductions through dimming. From the municipal perspective the problem appears unresolvable on the urban scale: Cities cannot afford to equip all their light points with calibrated metering systems. 'You need €30,000 for such a control device. That's tax money' explained the head of the SenStadtUm lighting team. 'You can only prove that this is efficient, if you achieve an effect in the end.' The scientifically evaluated 'big pilot project' in Leibnizstraße was one thing. But, according to the civil engineer, the reduced energy consumption does not cover the costs of new metering devices for every luminaire. 'You can't justify it in a city at large.'(SenStadtUm civil engineers, 2012-12-05).[346]

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[346] OV: *"Sie brauchen 30.000 € für so ein Steuergerät. sie können das Geld, Steuermittel, nur dann. also sie können das ganze ja nur nachweisen, dass das ganze wirtschaftlich ist, wenn sie am Ende irgendeinen Effekt damit erzielen. […] Das, was wir an Energie sparen, hat die kosten bei weitem nicht gedeckt. Wir haben das*

The Berlin civil engineers therefore called for more powerful allies to solve the problem. They argued that the metering issue needed to be tackled by the lighting industry or through political market regulations: If lighting manufacturers want to sell dimmable LED systems, they should also provide calibrated metering devices for their dimmable lighting systems. If the EU or German government wants to reduce the European carbon footprint, they should provide a legal framework that allows cities and communes to renegotiate the terms and conditions of the contracts with their electricity suppliers. Yet although Berlin is not the only city affected by the metering problem (sustainability consultant (EU), 2012-28-11), no solution to this energy calculation problem has emerged thus far. A SenStadtUm employee believes it is a case of market failure. ‘There is no pressure’, because there are few who want to dim their lighting systems. Against this backdrop, the civil engineers described the project as a failure.

In addition to that, the project became even more heterogeneous in the planning process when the Loss of the Night research cluster chose Leibnizstraße for its studies on the social, ecological and visual effects of the new LED system. In order to do so, the ecologists tried to ‘enrol’ insects[347] and the urban planners and social researchers mobilised residents to answer their survey. The difficulties which the scientists encountered in the course of their data collection and analysis raise methodological questions, which in turn highlighted more general translation problems between lighting professionals and laypersons: ‘High shares for the answer ‘don’t know’ indicate […] that the respondents do not always believe themselves capable of making a qualified assessment’ (Besecke & Hänsch, 2015, p. 236). Furthermore, the diversity of responses suggested that the appreciation of the new lights was to a large extent a question of personal taste. The researchers concluded in their study on Leibnizstraße that more *in vivo* research on citizens’ perception of public lighting is recommendable, especially comparative studies based on ‘standardised question schemes and valuation categories’ yet to be developed. In line with their research programme, they see a need for ‘sensitising the public to the issue of “light pollution”’ (Besecke & Hänsch, 2015, p. 247).

Although the project was also designed as a public experiment from the very beginning, SenStadtUm appears to have been little involved in the research activities. They refer to the

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alles als großes Pilotprojekt und mit wissenschaftlicher Begleitung—und dann haben wir das gemacht, aber in Größenordnung können sie das in der Stadt nicht rechtfertigen” (SenStadtUm civil engineers, 2012-12-05).

[347] Although I have not paid particular attention to the ecological studies I am sure that we could find ‘interessement devices’ that are very similar to those described by Michel Callon in his example of scientific research on scallops (Callon, 1986b).

project as a ‘big pilot project’ with ‘scientific monitoring’.[346] From an ‘interessement’ perspective, one might argue that the interests of SenStadtUm and the academic stakeholders in the project were never fully aligned. While SenStadtUm envisioned a demonstration project, the scientists were looking for suitable field sites. As a result, the project was a hybrid from the beginning. To me it seems that an ‘urban laboratory’ with both scientific and political appeal could have functioned as a point of shared interest. Yet as we have seen, the Senate Administration has little space for such experiments.

In this respect, Falckensteinstraße is a contrasting example. Here it seems that the political end justified the means. The public staging was well prepared and successfully displayed the new LED solution in front of heterogeneous audiences. The project can be considered a ‘display of virtuosity’ that enrolled the relevant actors to an extent that LED gaslight imitations are now being implemented on a large scale in the district of Neukölln. In contrast to Leibnizstraße, all relevant actors and entities were known and interested in the process. As in the case of Place Bellecour, the process involved a series of tests and trials.

The technological solution was carefully tested and proven before its public display, first in private and in the TU lighting technology laboratories, then in several streets in Neukölln and Kreuzberg that were off the gaslight protesters’ map. The collaboration between installer, manufacturer and SenStadtUm was also stable and all three had an interest in finding public acceptance for the gaslight replacement. During the installation in Falckensteinstraße everything went ‘hand in hand’, although the project was carried out in a great hurry (NSR, 2012-11-14b). The installation was completed within two weeks, just in time for a site visit with local media before the gaslight amateurs’ demonstration on the following day.

Key ‘interessement devices’ included the TUB prototype luminaire in the early planning phase and, during the presentation, the iron-cast *Bündelpfeiler* poles and, most importantly, the authentic familiar atmosphere of the refurbished street.[348] The favourable outcome of the display seems also due to the fact that SenStadtUm was able to *show* convincingly, that they would not alter the look and feel of West Berlin’s gaslit residential areas. In other words, they showed that the existing relationship between the citizens and their familiar *Kiez* would

[348] In this respect, the case also reveals the methodological limits of the ANT model, which seems less suited for analyses of ‘immaterial’ relationships that relate to cultural perceptions and personal familiar engagements (Hasse, 2007a; Hirdina, 1997; Thévenot, 2007). In this respect, non-symmetrical ethno-methodological or phenomenological approaches seem more useful.

remain the same. Against this backdrop, I consider the LED installation in Falckensteinstraße a municipal display of virtuosity that was aimed at re-establishing a trusting relationship between the Berlin public lighting services and the concerned citizens and reinforcing a working relationship between the Berlin public lighting service and the new and old lighting technology in its custody. The development of the LED gaslight imitation from a prototype at the TUB to a public display in front of an extremely heterogeneous group of observers is quite remarkable, especially as the display in front of the press and indignant gaslight amateurs was positively evaluated by most of the participants.

Last but not least, the technology performance in Altonaer Straße is a model case of interessement. Yet since in this case, the installation was only temporary, I could not explore whether the newly established socio-material network was stable and how it developed between the poles of testing and showing.

We can conclude that 'following the actors' revealed the pragmatic testing that accompanied the introduction of LED lighting. The 'application success' of early public LED installations depended not only on the actors' technological competence and willingness to share the financial risk (W. S. Baer et al., 1976). It also depended on their social skills and ability to 'translate' their ideas for relevant allies (Callon, 1986b). Against this backdrop, it seems no coincidence that the Lyon spokespeople of LED lighting were lighting designers. With a professional background that involves both urban and architectural design and light engineering, they knew the 'language' of monument preservationists, space users and the DEP engineers.

From the ANT perspective, the 'failure' in Leibnizstraße appears to be a model case of insufficient 'interessement' (Akrich et al., 2002a; Akrich et al., 2002b). In contrast, the cases of Falckensteinstraße, Place Bellecour and Montée du Boulevard are successful examples of network formation. The Lyon test streets and the technology performance in Altonaer Straße seemed less challenging in terms of forging stable networks of heterogeneous actors and things. Instead, these last two cases raised another question, namely the question of how the project planners managed publicity and privacy in the public spaces of Lyon and Berlin.

7.1.2 Following the attention: Managing 'privacy' and 'publicness'

As early studies on state-funded technology demonstrations showed, too much visibility, particularly political attention, can be detrimental in innovation processes (W. S. Baer et al., 1976). At the same time, visibility is desirable when seeking to showcase innovation. Diffusion research shows that the production of evidence and dissemination of information is paramount for 'diffusion success' (Lefevre, 1984; Magill & Rogers, 1981). Yet the production of technological facts in real-life situations is all but trivial and is closely related to the social function of (urban) spaces, as pointed out by Adi Ophir and Steven Shapin:

> 'Within knowledge-making sites, epistemological and disciplinary distinctions are related to spatial arrangements that differentiate degrees of visibility, directness of access to objects of research, facility of movement between workplaces, and density of interaction among persons occupying different positions at different locations' (Ophir & Shapin, 1991).

Therefore, testing and showing innovation not only depends on the timing and maturity of new technology but also has an inherently socio-spatial dimension. Steven Shapin's historical account of early modern experiments showed that new scientific facts were tested in private spaces and shown in public or semi-public spaces like scientists' shops or gentlemen's residences.

Drawing on these insights we can compare the cases with regard to their socio-spatial characteristics. How did the project planners create semi-private places for their LED tests and manage the public visibility of their projects in order to shield or stage their public innovation activities?

The Rue Thénard and Rue de l'Oiseau Blanc test sites are most revealing in this respect. As outlined in the case study (6.1.2), both streets are located in peripheral residential areas of Lyon. They offered the DEP planners not only a typical setting in which to explore the advantages of LED lighting as a replacement for HPM luminaires, but also a calm test field where they could observe the new technology and its technical performance throughout its life span in real-life spaces and in real time.

In contrast to urban landmarks like Place Bellecour, the streets fulfil no symbolic or connecting function within the city space. Situated on a hill, Rue de l'Oiseau Blanc feels remote from the city centre. A steep serpentine road connects the hill to the old town. It is mostly used by motor vehicles. While the centre of Lyon has become bicycle friendly, my self-experiment showed that this area of Lyon is far less inviting for cyclists (NSR, 2011-11-29b)— although there are also rent-a-bike stations on the hill and one next to Rue de l'Oiseau Blanc. Buses and a funicular connect the hill to the Metro and the urban public transport network. Most of the residents I met when I visited the street arrived by car. In terms of public lighting, this is not irrelevant, since light is perceived differently by pedestrians than from the drivers' seat of a car. The only pedestrian I talked to in Rue de l'Oiseau Blanc had immediately perceived the new lights although she did not even live in the street and only visited friends from time to time. In comparison, Rue Thénard was closer to public transport and I also met more pedestrians. One of them gave a detailed account of the changes in light levels and light distribution. Although these observations do not qualify as evidence in statistical terms, they still show that the residential streets are not places of special public interest. They are not busy shopping streets, they have no important connecting function and they are rather remote from the city centre. Against this backdrop, they seemed well suited for the DEP's intra-organisational technology tests.

This conscious spatial attention management, as I call it, is also reflected in the DEP's more general approach. As the explanation of the head of the maintenance department shows the DEP also chooses places in order to create 'publicness' as in the case of an LED installation on a bridge:

> 'The consensus was to use LED lights in conspicuous places. At first, we started with just a few places. We put an LED lantern in a small street in the second arrondissement, and two on a street with very little traffic. Then we said, "OK, this is working," so now let's try it in a busier spot… In any case, all the bridge installations are quite old and we intend to change them. So we think, "here's an opportunity to try it on a bridge." So we pass by every day, see how it looks, and maybe we even see how the residents react" (DEP head of maintenance, 2012-01-18).[349]

[349] OV: *« On avait la volonté d'utiliser des LEDs dans les endroits qui soient visibles. Au départ on a commencé juste à quelques endroits. On a mis une lanterne à LED dans une petite rue dans le deuxième arrondissement, deux dans une rue où personne ne passe. Et si on se dit 'ca fonctionne' donc maintenant on va essayer dans un endroit très passant […] Tout les installations sur les ponts sont très anciennes et on a la volonté de les modifier. On se dit, 'c'est l'occasion on l'essaye sur le pont.' On y passe tous les jours, on voit ce que ça donne, on voit aussi la réaction des Lyonnais éventuellement »* (DEP head of maintenance, 2012-01-18).

There was no public reaction. The light levels had not changed noticeably, the technology functioned as it should and hence the new installation did not affect the everyday uses of the public space.

In Berlin, SenStadtUm tested LED gaslight replacement in residential streets in Neukölln and Kreuzberg. They offered a similar semi-private setting for gaslight replacements as they lay outside the focal areas of the gaslight protest, such as Charlottenburg and Frohnau, with their historic gas-lit architectural ensembles. When asked whether there had been any complaints from residents, a SenStadtUm employee suggested that the residents of Neukölln had 'different problems' (NSR, 2012-07-16).[350] The area around Saalestraße, where I observed the dismantling of gas alignment lamps and the installation of LED pole-top luminaires, is a target area of a number of 'Social City' initiatives (*Soziale Stadt*), a federal scheme that helps German cities to develop their disadvantaged neighbourhoods, to promote social cohesion and participatory urban development processes.[351] Where public lighting is concerned, vandalism is by far the greater problem than the destruction of Berlin's cultural gaslight heritage. When I visited Saalestraße again, shortly after the LED installation, the first brand-new lanterns had already been smashed.

While the Lyon test sites and the low-interest gaslight replacements in Neukölln offered the municipal project planners comparatively private public spaces for testing in public, other places were chosen in order to increase the visibility of the new installation. In the unfortunate case of Leibnizstraße, SenStadtUm deliberately chose a site in the 'City West' in anticipation of a technology demonstration. The street seemed more publically appealing, also for their commercial partner, as a civil engineer suggested:

> 'We had also thought that the manufacturer would be interested in advertising [the project] a little and in that case such a street in the City West is much more lucrative than a street in some Eastern District' (2012-12-11, my translation).[352]

Indeed, luminaire manufacturers seem to have a fine sense of place when it comes to advertising their products. The case of Altonaer Straße is exemplary in this respect. As we

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[350] However, when SenStadtUm started replacing 700 gas pole-top luminaires in Neukölln the head of the public lighting team received an angry call from the district monument preservationist (NSR, 2013-05-22).
[351] See: http://www.quartiersmanagement-berlin.de/English.40.0.html, 2014-08-14.
[352] OV: *„Wir hatten auch gedacht, dass der Hersteller ein bisschen daran interessiert ist, ein bisschen Werbung damit zu machen und da ist so eine Straße in der West-City sehr viel lukrativer als eine in irgendeinem Ostbezirk"* (SenStadtUm engineer, 2012-12-11).

have seen, the co-development team chose *not* to show their new LED luminaire in the previous sampling event in Afrikanische Straße in Berlin Wedding. Instead, they looked for a street with 10 meter-high poles for a more effective technology performance.

Altonaer Straße was not their first choice. Instead, the sampling event was first planned for another 'beautiful' main street in the city centre of West Berlin close to Bahnhof Zoo (product designer, 2012-11-14). But the project was thwarted. One week before the LED installation, underground engineering works transformed the street into a construction site. In search of an alternative location, they came across Altonaer Straße, found it perfectly suitable and successfully coordinated their sampling project with SenStadtUm and the Berlin light manager. One of the designers later described the street in the midst of the Berlin Tiergarten and next to the emblematic Berlin Victory Column on *Großer Stern* as a 'super location' and 'highly recognizable place' (product designer, 2013-08-22). Thus, the installation site offered much more than 10-meter-high lamp poles, namely an attractive urban image (see Figure 6-27).

The examples of Place Bellecour and Montée du Boulevard were equally useful in terms of product marketing, as will be further outlined in the next section. Together with Falckensteinstraße they present a third, and also the most common category of spatial attention management, namely cases in which the installation sites are not deliberately chosen for their public appeal or relative privacy, but because they are in need of technological refurbishment or subject to urban renewal. In these cases, 'publicness' is managed as described above, through pragmatic testing, previous rehearsal and 'interessement'. In these cases the public visibility of the new light was effectively managed by closing or keeping the black box of public lighting closed, as illustrated in the case study on Falckensteinstraße and outlined above with regard to Place Bellecour.

We can conclude that the successful introduction of LED lighting also has a socio-spatial dimension. Project developers of early public LED installations carefully chose the urban sites for their projects and thereby considered not only technical aspects like the pole heights or their distance (as in the Lyon test streets). Instead, they seemed to associate urban installation sites with different degrees of 'publicness' or 'privacy' and managed their projects accordingly. Based on their understanding of the city and the connectedness[353] or symbolic

[353] For a conceptualisation of connectedness of urban spaces see the Space Syntax methodology (Hillier, Leaman, Stansall, & Bedford, 1976)

appeal of urban spaces, the planners categorised their cities into zones for private testing and zones for public demonstrations.

As argued above, this spatial attention management can be considered complementary to pragmatic testing: The 'interessement' of relevant allies and entities ensured that the newly introduced technology worked, that LED luminaires were compatible with existing public lighting infrastructures and routines and were socially acceptable. The 'spatial attention management' ensured that *only relevant* observers were interested in the public innovation activities. However, this does not yet explain how the production of evidence and information relates to the heterogeneity of urban audiences. After all, the case studies also showed that laypersons and professional groups perceived and evaluated 'the new' differently. This is due to the fact that what counts as evidence depends on the observers' perspective and expertise (cf. Rüb & Straßheim, 2012). Applied to contexts of innovation, the recognition of 'the new' as something 'better' (Braun-Thürmann, 2005) is less 'evident' if the observers do not share the same perspective, or if they engage differently in the innovation activities. Against this backdrop, the next section focuses on situated evidence production and site-specific information.

7.2 LED light in place: 'Truth-spots' and 'investments in form'

In order to reconstruct the six case histories I relied on the actors' accounts of the projects. As we have seen, their perspectives, the information they gave me and the evidence they had derived from the projects varied. For instance, the DEP planners referred to what they had learnt about LED light *in use* in a particular situation and whether they could apply this new knowledge somewhere else. Their SenStadtUm colleagues were more concerned about whether LED technology was a justifiable option, especially in terms of cost, and whether it was acceptable or desirable for public and private stakeholders. Residents were, with the exception of the Berlin gaslight amateurs, rather inconsistent informants, as their accounts of the new lighting situations varied. Finally, and not surprisingly, manufacturers were good at telling success stories about their products.

Confronted with these plural perspectives I tried to categorise the information and evidence production I observed. The aim was not to give a complete and comprehensive account of every single piece of evidence or information but to reveal group-specific patterns in how they are produced. Accordingly, the leading question was more generally: who showed what to whom? Based on the answers to this question I tested my thesis about the *site-specific* introduction of LED lighting.

The following case comparison draws on Gieryn's 'truth-spots' and Thévenot's notion of 'investments in form' as a conceptual framework. As outlined in chapter 2.2.3, Thomas Gieryn's notion of truth-spots highlights the relevance of social spaces for evidence production. In his terminology, the six LED installation sites can be described as *field sites*—as 'places celebrated'. As we will see below, the actors' evidence and information made explicit reference to the particular urban situations. In addition to that, Falckensteinstraße and Altonaer Straße also showed *farm-like* elements, in the sense that they were also places of display and performance (Gieryn, 2002, p. 123). The laboratory practice of denying the place of truth production seemed only relevant in the case of the photometric measuring activities in Leibnizstraße. Whereas Gieryn only refers to scientific evidence production I apply his conceptual toolkit to analyse non-scientific pieces of evidence.

In the context of innovation, the focus on the spatial dimension of showing addresses the question of how *situated* evidence can be transformed into information that *circulates*, in other words, how site-specific early LED experiences can facilitate the valorisation of an innovation or be of use to other LED users of producers in different situations. In this respect, Laurent Thévenot's notion of 'investments in form' offers a pragmatic point of departure. These investments 'prepare the environment to facilitate action coordination' (Thévenot, 2007, p. 414). They are audience-specific as they engage heterogeneous actors and groups differently:

> 'Such investments imply costly construction operations that in return yield coordination output that varies by three characteristics: *time span, spatial extension and the solidity of the related material equipment*. The idea was to show that the required "enforming" of information is linked to actors' *coordination modes*' (Thévenot, 2007, pp. 414, my emphasis).

Accordingly, 'investments in form' relate to professional visions and the different 'familiar worlds' of lighting experts, residents, amateurs and politicians and their engagements. The notion thus highlights the *social dimension* of site-specific information production. The same information about a situation is not received by everyone in the same way. What is perceived and accepted as evidence, as 'unquestionable certainty' (unhintergehbare Gewissheit, Rüb &

Straßheim, 2012, p. 380), lies in the eyes of the beholder, that is, depends on her or his professional vision, habits, expectations. This does not mean though, that the production of evidence and information is arbitrary. Thanks to conventions and habituation innovators can rely on the fact that some formats and forms are more engaging than others. In the following I will describe three formats that seemed particularly relevant for light-technological innovation, namely photometric data, site visits and images. As Figure 7-2 suggests, their potential to coordinate or inform innovation-related interaction differs with regard to the above-described characteristics of time span, spatial extension and solidity.

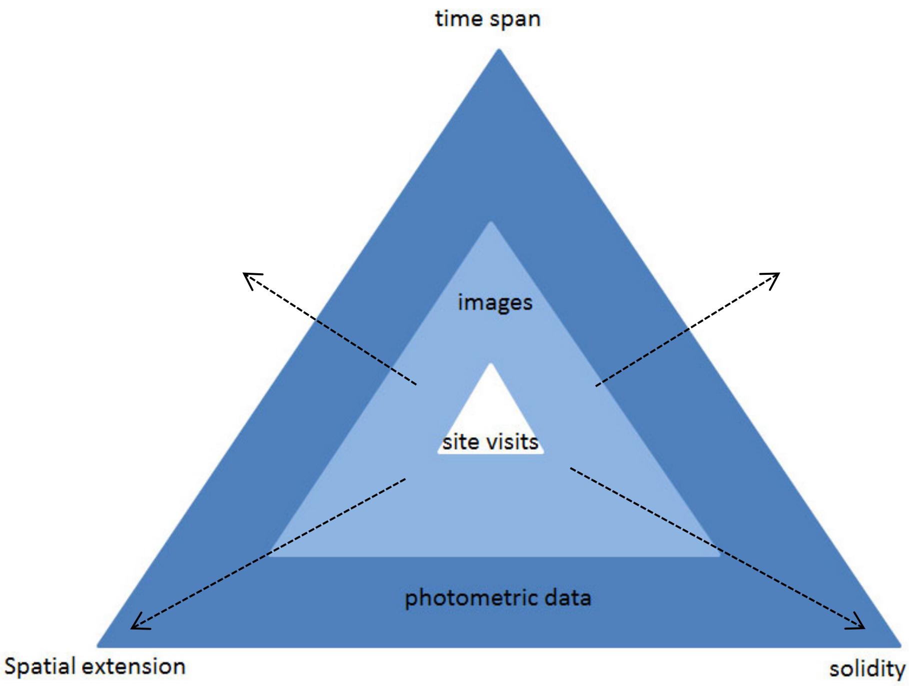

Figure 7-2: Photometric data, site visits and images as project-related 'investments in form'.

7.2.1 Community-specific: Photometric data

The brightness of a luminaire, its light distribution curve and nominal connected load are key values that can be found on any LED product sheet. In theory, they constitute a highly mobile kind of information that is purified through laboratory tests and hence deprived of the socio-material contexts of its production. In this section I limit my analysis to photometric figures and numbers that are relevant for the evaluation of good lighting practice.[354]

[354] This does not imply that energy-related numbers and figures are less important. On the contrary, they circulate even better and producing them is all but trivial. In Berlin, gaslight amateurs contest the official numbers and

Photometric values are produced through standardised measuring procedures that are also laid out in the EN 13201 and guarantee their general validity. As they are based on lighting engineers' expert practices, they are of limited use for lay audiences. Drawing conclusions from information on the colour rendering, colour temperature, the light distribution of a luminaire and its efficacy requires some deeper understanding of light and lighting, photometry and experimental practice. On the other hand, the significance of performance-related data is relative in practice.[355] Whether LED technology performs better than conventional technology cannot be decided on the basis of product sheets alone. It also depends on site-specific factors such as the width of a street, the surrounding built environment and the materiality of any horizontal and vertical surfaces.[356]

During my participant observation, I identified two expert ways of producing photometric data, that is, performance-related evidence on light levels and light distribution, which I categorised as scientific and practical. The following two examples *are not* city-specific but relate to the different professional practices and goals of municipal and academic lighting engineers.

The *practical* approach could be observed in the Lyon test streets, where the DEP head planners took performance measures in a rather relaxed way. What was measured was not the product performance as promised by the manufacturers but the adequacy of the LED installation in the specific urban space. The measurements were thus not compared to other LED or HID products but to the situation before the installation. The evaluation was intended to clarify whether the streets were now more adequately lit than before.

To produce these data, the DEP planners used the appropriate measurement equipment, a lux meter and luminance meter; however, they used them in a rather sloppy way. On site, they discussed the rough measurements of the luminance and illuminance levels in Rue Thénard and Rue de l'Oiseau Blanc and matched the results with what they saw. The measurements

figures concerning the energy savings that SenStadtUm provides for legitimising the electrification. Furthermore, the Leibnizstraße case shows that the production of such data depends on the legal and social acceptance of measuring devices. No calibrated meter means no valid data. For an account of the historic development of measuring procedures for producing data on the energy consumption of artificial lighting see Chris Otter (2008).

355 Similarly, and as pointed out above, installing luminaires in line with scientific performance standards, like the road lighting standard EN 13201, does not guarantee good results. As a lighting engineer remarked, 'it can only prevent the worst' (TUB lighting engineer, 2013-02-06).

356 This is also why product performance data played a minor role in my case descriptions and analyses, which is not to say that they did not matter in the procurement process. Of course, light planners choose and evaluate products on the basis of their performance parameters.

allowed them to form an opinion about the homogeneity of the light levels, light spills on facades and potential glare. Before the conversion to LED, they had already carried out more precise measurements so that they could also compare the new measurement to previous situation. Based on what they saw with their trained eyes and on what they measured, they came to the conclusion that LED lighting was an improvement in terms of light quality. The streets were more homogeneously lit and there was less straying light on adjacent private properties.

As in the case of Place Bellecour, where the lighting designers organised a mock-up and the planners took measures on site in order to compare different lighting solutions, these data were produced with reference to the *specific* installation site and were not for circulation. Accordingly, the light planners relied on their visual impression and, as I said, applied the measurement devices and techniques in a sloppy way, that is, in a free-handed way that was only roughly in line with standard scientific procedures.

In contrast, *scientific* evidence production was performed in the course of the Leibnizstraße case. As pointed out before, the TUB lighting engineers encountered some problems. After all, the street is not a lab. Nevertheless, they did their best to produce reproducible data. One night, I accompanied a group of PhD students on a field trip and could observe how the practical free-handed style differs from the quasi-experimental.

In contrast to the DEP planners, the TUB students performed their measurements in accordance with the standard procedures as outlined in the EN 13201. In Rue de l'Oiseau Blanc, the civil engineers had handed me the lux meter and told me to point it on a spot on the street in 'about 60 meters distance' in order to measure the lux levels on the street (NSR, 2011-11-29a). In Berlin, the TUB students took exact measurements, turning a two-lane residential street into a laboratory-like setting. With a very large compass we subdivided the road surface between the light poles into a raster of ten times three evenly distributed points[357] and then took measurements at every single point. The data we produced seemed messy as the following passage from my field notes illustrates:

> 'The lux meter oscillates and the deviation is quite high […] It is P. who decides when he pushes the hold button of the lux meter to get a value. We joke about the arbitrariness of the data' (NSR, 2012-05-08).

[357] EN 13201 also explicates how the raster should be produced.

The data were not evaluated on the spot like in Lyon. Instead, the lighting engineers took the data to their laboratory where they processed and rendered them on the computer to produce significant photometric values. The process corresponds with what Bruno Latour describes as 'inscription' of scientific facts. In Thévenot's terms, the process can also be considered as an investment in form: In order to produce meaningful facts, the TUB lighting engineers spent time on site with a car-load of measuring equipment including special cameras, lux meters and the oversized compass. Furthermore, they relied on previous investments in form, like the European standard and standard computer software, to make their results reliable. Last but not least, producing this evidence required an education in lighting engineering.

With regard to the spatial dimension, these two examples of practical and scientific evidence production also relate to different types of truth-spots. The DEP planners' approach accounted for the complexity of the situation by synthesising photometric measurements and personal visual impressions ('it looks quite good'). They explicitly accounted for site-specific material surroundings such as pole distances, front yards, narrow pavements and house facades. In that sense, the test streets functioned as a field, a 'place celebrated'. In contrast, the scientific approach aimed to standardise the site of evidence production in a laboratory-like manner, as the following field notes suggest:

> '[The PhD student] tells me that *in vivo* measurements are very imprecise. He conveys a rather low opinion of data from the field. […] it is very difficult to find a street where the required distance of 60 metres between the camera and the first measuring point can be achieved as requested in the norm. Streets either bend a little bit or there are crossroads that lie between the measuring points […] Measuring outside where cars intervene, the asphalt is different and not homogenous *(Spurrillen)*, and where the distances between the posts are not the same, makes it difficult to say something about the quality of a luminaire (NSR, 2012-05-08).

Against this backdrop, one can argue that scientific photometric measurements in real-life situations make it necessary, to a certain extent, to turn urban test sites into laboratory-like 'denied places' (Gieryn, 2002).

In the context of innovation, the practical way of producing and referring to photometric data also fulfils different functions than the scientific method. The lighting engineers produced the data to prove and test laboratory results in the real world and to specify technical performance standards. Their evidence is meant to circulate in the form of papers, posters or presentations, in science conferences, standardisation working groups or expert conversations. In contrast, the practical approach produces evidence for internal purposes, *for intra-organisational* circulation and future planning. 'Experiments' are understood accordingly as a DEP planner explained:

> 'An experiment is the real thing because, for us, when we experiment... often we leave them in place, to see how long they last. So it's the real thing. It's an installation. We call it an experimental installation because it's different than the majority of what we do' (2012-01-06).[358]

Thus, the data measured on site also do not stand for themselves. They are *situated* and linked to site-specific information and city-specific experiences. Although 'practical' data are also inscribed they circulate differently. Instead of contributing to an abstract body of scientific knowledge, they add to the personal and collective expertise of organisations like the DEP or SenStadtUm. What the civil engineers learned about the performance of LED products on site will inform their decisions in the future (2012-01-25).

To conclude, references to photometric data can be considered a highly mobile format of evidence produced by lighting engineers for lighting engineers, in other words, for a homogeneous expert community that knows the terms and condition of evidence production and understands how these data should be interpreted and how they relate to real-life situations, for instance, how they are influenced by material surroundings like private lights and light reflections from the road and vertical surfaces or trees, etc.

Photometric information on the illuminance and luminance in a lit space or the TI value for glare or CRI values for colour rendering means little to lay observers. As an investment in form, the production or reference to photometric data thus serves to evaluate and justify early public installations within the expert world of professional light planners. The Berlin controversy about the correct production and interpretation of such data shows the limits of these investments as a format for public justification and quality criterion for urban light planning: While the light planner claimed that the lighting engineers' evidence production was too scientific and impracticable for municipal lighting practice, the lighting engineers insisted that the Berlin light panel's alternative way of measuring quality was inappropriate and

[358] OV : *« Une expérimentation est réelle parce-ce que nous, quand on fait des expérimentations …e… souvent on les laisse en place pour voir la durée de vie. Donc, c'est réel. C'est une installation. On dit que c'est une installation expérimentale parce-ce qu'elle différente de celle qu'on fait en majorité »* (DEP lighting engineer, 2012-01-06).

invalid (5.3.1). One could say that from a lighting engineering point of view, the expert panel's evidence production was too situated. It too much 'celebrated' the places of Berlin.

7.2.2 Boundary-crossing: Site visits

Visits to the installation sites were crucial moments of evidence production in all six cases. They offered actors the possibility to experience the new light, to discuss its advantages and problems and to communicate LED installations across disciplines and across boundaries between experts and lay audiences. As such, site visits can be considered to be investments in a coordination format, which are very limited in terms of time span, spatial extension and material solidity but still relevant in the context of light-technological innovation activities.

Site visits are part of every light planning process as they allow the actors involved to test and adjust their designs and to take well-informed decisions. In this respect, the mock-up on Place Bellecour is exemplary. Yet as the technology performances in Falckensteinstraße and Altonaer Straße show, they are also effective means for communicating and coordinating planning processes across transdisciplinary boundaries or for showing innovations to lay audiences.

Compared to photometric data, the format of the 'site visit' is more suitable for producing easily accessible and comprehensible evidence that can be understood by both experts and lay people. Site visits are less effective in offering *generalisable* information. But as already suggested by Magill and Rogers (1981) they are highly valuable information sources for potential innovation users as they offer opportunities for problem-oriented information exchange. Thus, they can be considered as investments in form that turn installation sites into *farm*-like truth-spots: 'places of display' where observers are invited to see not only that an innovation works but how it works (Gieryn, 2002).

At the same time, site visits also show elements of non-scientific *field* sites, as they involve actors from different backgrounds in a process of collective inquiry. In Falckensteinstraße, for instance, media representatives and gaslight amateurs were invited to see for themselves and encouraged to produce their own evidence in a place 'celebrated' for its authentic nocturnal atmosphere. By demonstrating that the look and feel of Falckensteinstraße remained untouched by the refurbishment, SenStadtUm undermined one of the gaslight amateurs' most widely understood and hence most powerful arguments, namely the claim that gaslight 'feels like home' and electric lighting will destroy this celebrated familiar world (NSR, 2012-11-14a).

When comparing the site visits that took place *after the completion* of the six LED projects, we find that they were organised by different groups of actors. In Berlin, SenStadtUm was most active in inviting interested publics to come and see the newly installed light. They organised an inauguration event for Leibnizstraße and a press conference in Falckensteinstraße. Altonaer Straße is a different case as it was only a temporary installation. Here, the design team consisting of a lighting designer and the LED manufacturers invited their potential municipal clients to see a new LED product in real life.

In Lyon, the DEP planned and supervised the installation processes but let others present the results to interested publics. The regional Cluster Lumière and the city-network LUCI took their international guests to see the LED lights on Place Bellecour as part of their official programme during the 2011 Fête des Lumières (NSR, 2011-12-06 2012-01-17). The lighting designers and manufacturers of the projects guided the visits and answered questions.[359] In Montée du Boulevard, the manufacturer took a group of Brazilian clients to the staircase with the new free-floating LED luminaires. The product manager reported that the site visit took place without the DEP planners and that it was not their aim to communicate their projects in public in any case: 'They see if it works well and then do it again elsewhere but they do not talk about the implementation' (product manager, 2013-10-04).

When focusing on site visits *during the planning process*, the cases of Place Bellecour, Falckensteinstraße and Altonaer Straße showed that they facilitated the coordination, choice and valorisation of LED technology in the installation process. In particular, they facilitated the negotiation of diverging interests. This is because site visits do not take place in silence but offer the spokespeople of innovation the chance to engage and interact with potential allies who are also present. In Falckensteinstraße, the LED manufacturer and Berlin state secretary related the visual evidence to information about the production process and political decision making. In Altonaer Straße, the lighting designer's speech fulfilled a curatorial function in the sense that he offered his heterogeneous expert audience equally heterogeneous public justifications of the new product. For the lighting engineers he provided information

[359] According to the lighting designer, the international guests were primarily interested in energy savings. This reaction is not too surprising if one considers a) what has been said above about the generalisability of site-specific information and b) the highly site-specific LED solution on the vast square.

about technical and photometric parameters, for the municipal urban designer he highlighted the aesthetic qualities of the luminaire design. Well aware that the urban designer 'liked' the old luminaires and had a say in the procurement process, he also explained why they had slightly modified the luminaire case and made it shorter than the original: Thanks to their compact integration of driver, LED modules and thermal management the design team had been able to make the linear LED luminaire smaller and hence to reduce the material needed to produce it. His 'green' public justification can be understood as an attempt to juxtapose the Berlin-specific aesthetic argument with a 'cradle to grave' argument, which is understood across the EU. During other site visits, I observed similar negotiations, and there were similar juxtapositions of locally and globally applicable valuation criteria (NSR, 2012-01-17, 2012-09-12/13/14).

Against this background, guided site visits can be understood as an investment in form that engages heterogeneous audiences and bundles diverse perspectives. In contrast to inscribed and purified data that are well suited to crossing space and time, site visits are ephemeral and depend on co-present audiences. Yet they seem particularly useful for producing evidence that crosses professional and cultural boundaries and for conveying information that would otherwise be difficult to communicate (cf. Schulte-Römer, 2013c).

To conclude, nocturnal site visits are an important, if not indispensable part of urban light planning (Brandi & Geissmar-Brandi, 2007; NSR, 2013-09-19). As investments in form they are characterized by a *short time span*, a *very limited spatial extension* and *ephemerality* rather than material solidity. They nevertheless fulfil a coordination function, as they allow observers from different professional backgrounds as well as amateurs and lay audiences to form their opinion and to ask questions. In the planning phase, they can also fulfil a feedback function as they allow innovators to acknowledge and react to diverging expectations. After the completion of projects, they can facilitate the valorisation of innovations and help innovators to communicate their achievements to potential imitators. The co-presence of presenters and audiences can thus be considered a crucial advantage of this short-lived, situated investment in form. Last but not least, and unlike purified data, site visits allow their participants to switch between familiar, strategic, exploratory and public engagements.

7.2.3 Overflowing: Image production

It is not just the Lyon test streets that have left a public record; indeed all the projects have left their traces in the internet in the form of images. They are published on the websites of manufacturers and lighting designers, and in the case of Falckensteinstraße even on the website of the Berlin Senate Administration. As we have seen above, the production of image material was important in the case of Altonaer Straße, where the installation site functioned as urban scenery but also as a 'truth spot'. Spectators can immediately tell that the Berlin Victory Column is real. In a similar case in Lyon, the same international manufacturer installed LED luminaires on a bridge right in front of Lyon's basilica *Notre-Dame de Fourvière* on the hill. In this case, the image did not only show that the luminaires had been installed in reality but also showed the world of lighting that the City of Light approved of LED lighting.

The same manufacturer was also involved in the Montée du Boulevard project. The article in the company's corporate magazine presents a perfect example how early public installations can be exploited for the production of situated evidence.

The article emphasises the perfect match between the lighting technology and its urban site. The PR text valorises the new LED product by mobilising three urban contexts in particular: First, the installation is presented as an 'intimate light project that puts people first' (Arnaud, 2013, p. 32). The homogeneous warm white light is designed to create a friendly nocturnal environment and to add to the safety and well-being of those who use the stairway on a daily basis. Second, the canoe-shaped LED luminaires evoke the particular sense of the place. The lights 'highlight the historical ramparts of the city'. The canoe-shaped luminaires are linked to the *Croix Rousse* district's 19th century silk weaving tradition and poetically described as 'floating silkworm cocoons' (Arnaud, 2013). Third, the LED garland of light points underlines the natural topography of the slope and serpentine of stairs. Images and sketches by the lighting designers not only support the argument, they make it comprehensible. Without them it would be very difficult for a reader to grasp the notion of the 'floating silkworms', the design concept of the garland or the wild-romantic atmosphere of the place.

A favourable and glossy image of the upper part of the path (Figure 7-3), shot in the 'blue hour' from an extraordinarily advantageous angle,[360] shows all relevant features of the new

[360] I tried to reconstruct the photographer's position and came to the conclusion that he must have stepped on a ladder or wall in order shoot the picture from this perspective.

urban LED configuration at one glance: the view over the city, the user-friendly design personified in a pedestrian and the enchanted wilderness around the well-lit path.

Figure 7-3: A glamorous stairway: the manufacturer's view © and my photo (CC).

The article was published long before the DEP planners had approved of the installation and handed it over to their maintenance unit. The manufacturer's smooth switch from piloting to product marketing can be considered a special skill or competence of this particular company. This does not mean that Montée du Boulevard is a special case in terms of image production. In fact, it is the rule.

Images are crucial for any light-related project documentation. As already mentioned, lighting designers and manufacturers prefer the twilight of the blue hour when the surroundings and material parts of their lighting designs are still visible and the artificial light nicely merges with the last glimpses of daylight. However, such visual 'celebrations of place' always feed the suspicion, especially in times of picture editing software, that the reality of projects might be less appealing and perfect than its representation in the photograph, as the following little anecdote shows. During a conference in Rotterdam I attended a site visit to an award-winning project. All participants on the tour were very familiar with the project, as it had been discussed and presented in text and image form in various professional magazines and presentations. Yet when we arrived on site, the enthusiasm of the visitors was enormous—not because the project looked better than expected but because it looked *just as* expected: 'It really looks like on the photographs!' said a French lighting professional with amazement (Schulte-Römer, 2014b, p. 88).

I conclude that images can travel far and still celebrate the urban environment and atmosphere of a site-specific installation. They offer a unique opportunity to understand the idea behind a lighting design and its realisation. However, images also raise suspicion and offer mono-perspectival information without the option of feedback. They offer observers who cannot visit the site or meet the planners a valuable source of information. They also speak to heterogeneous audiences. But in contrast to site visits and especially photometric data their interpretation is not prescribed or curated by experts. In the context of innovation, images present *engaging* investments in form that 'celebrate' the places of early public installations. Yet the site-specific information they offer is not the most reliable source.

As we have seen, the production of evidence and information was determined a) by the installation sites and their material characteristics as they were mobilised as 'truth-spots and b) by the personal engagement and perspectives of lighting professionals, amateurs, lay and scientific observers. However, the propensity to invest in these evidence-producing formats did not only vary across professional groups but also when comparing Berlin and Lyon as the following table shows.

	Photometric measuring	Demonstrative site visits	Image production
Lyon			
DEP	■		
Lighting designers	■	■	■
Manufacturers	■	■	■
Berlin			
SenStadtUm		■	■
TU Berlin	■		
Private light operator	■		
Lighting designers	■	■	■
Manufacturers		■	■
Gaslight amateurs		■	■

Table 7-2: The key actors and their project-related 'investments in form' (dark grey = activity).

The comparison reveals one particularly interesting difference. As Table 7-2 shows, the Lyon DEP has neither images on its website nor did the municipal planners organise site visits. Nevertheless, the projects on Place Bellecour and Montée du Boulevard fulfilled demonstrative functions after their successful completion since their project partners and Lyon-based organisations like the Cluster Lumière and LUCI showed the projects to international guests or clients. In contrast, SenStadtUm was more active in showing its projects and organised site visits and inauguration events—also in other non-LED lighting projects that are not mentioned in this work (for instance the inauguration of the Yorck

Brücken). They also took pictures of Falckensteinstraße for the SenStadtUm website where any interested Berlin citizen can learn more about the LED gaslight projects.

While the Lyon DEP engages actively in the production of photometric data—practically for intra-organisational purposes or scientifically in the course of the EVALUM quasi-experiments, SenStadtUm allowed the TUB lighting engineers to use Leibnizstraße as a field site but did not actively engage in the scientific design and evidence production.

Finally, the lighting designers and LED manufacturers involved in the projects were most active in producing images of their designs or products in urban spaces. Yet as far as my data collection goes, the Lyon images travelled further than the Berlin photographs. While pictures of Place Bellecour and Montée du Boulevard are published on the manufacturers' and lighting designers' websites and magazines. The images of LED imitations of gaslight can be admired on the SenStadtUm website. However, although Berlin is supposed to be the world-heritage site for gas lighting, it was a municipal representative from Leipzig who was invited to present their small-scale LED gaslight refurbishment project in an international conference in Lyon (NSR, 2011-12-08a).

Against this background and based on the assumption that testing and showing are performative practices that mobilise audiences and thus shape innovations I will now focus on the urban scale and first ask how the different test-show patterns in Lyon and Berlin can be explained. In the second step, I will demonstrate that LED lighting was installed and perceived in different configurations, due to city-specific socio-material public lighting networks and publics.

So why is it that the Lyon municipal project developers tended to test while the Berlin decision makers were more inclined to show the technology? And why is it that Lyon projects nevertheless turned into demonstration projects?

7.3 Comparing cities: Explaining puzzling patterns

The case comparison revealed three puzzling city-specific patterns. First, and as pointed out above, Lyon seems more inclined to test LED technology, while Berlin seems more interested in showing it. Nevertheless, the Lyon projects are more widely acknowledged in the 'world of lighting'. Second, the graphic (Figure 7-1) shows that the Lyon projects remained quite stable regarding the *level of heterogeneity* of the actors and groups involved. The clear direction of the Lyon project trajectories from testing to showing and their stable level of heterogeneity can partly be explained in terms of successful socio-material project management and socio-spatial attention management, as outlined above (7.1). Similarly, the increasing heterogeneity in the case of Leibnizstraße was described as a failure to interest and enrol all relevant actors and entities from the start of the project, while the heterogeneity of the actors and audiences in Saalestraße and later Falckensteinstraße was deliberately increased while the LED solution was developed and ultimately presented in public. (Since the technology performance in Altonaer Straße was only temporarily installed, I consider it a special case and will not consider it in this analysis.) Third and most importantly, there is a third puzzling difference regarding the *LED configurations* in both cities.

My argument is that these patterns cannot be explained by solely focusing on the specific situations and following the actors and attention. Instead, we need to take a wider perspective and once again compare the very different public lighting networks of Berlin and Lyon. In doing so, I will develop my argument in three steps. First, I will argue that spaces for innovating in public were opened or blocked by the quality of *existing* heterogeneous relationships and the 'publicness'—in other words, the political standing'—of the public lighting networks (7.2.1). Second, this also explains why LED lighting played a different role in the two cities and why it was differently installed and perceived (7.2.2). Third, these city-specific configurations correspond with *city-specific publics* for urban lighting, which explains why the Lyon projects became known in France and beyond while the Berlin LED installations are locally relevant (7.2.3).

7.3.1 Innovating in existing public lighting networks

As Akrich, Callon and Latour outline (2002b), the success of innovations very much depends on the capacity of spokespeople to 'interest' all relevant entities, to test the commitment of people and the compatibility of things, and to mobilise them. Yet my case studies show that spokespeople were important but not decisive. In two of the three Lyon cases, lighting designers proposed LED solutions. In Berlin, the TUB lighting engineers were crucial for the introduction of LEDs, while SenStadtUm employees had varying degrees of success as spokespeople for LED technology. It seems that the spokespeople's 'art of interessement' is not all that matters.

In the following I will therefore show that those who spoke for LED lighting not only built new networks but also relied on *existing* urban networks. I further argue that the *quality* of the network ties varied. In Lyon, the DEP can be considered as a kind of lever: If an LED-spokesperson manages to attract the DEP planners' interest, the rest of the Lyon public lighting network will follow. The existing stable ties between the heterogeneous actors make it easier to manage heterogeneity from the start. In Berlin in contrast, the small municipal public lighting unit seems to have very limited leverage. The heterogeneity of actors and entities is generally problematic, not only during early public LED installations. In this situation, according to my argument, innovation projects become politicised situations in which, instead of testing the new technology, the actors involved mutually test their roles and relationships in the public lighting network. It seems that the mediated heterogeneity in the Lyon public lighting network allows its actors to 'engage in exploration', while the problematic heterogeneity in Berlin calls for well-staged and prepared 'public engagements' (Thévenot, 2007).

The cohesive Lyon public lighting network revisited

Heterogeneity seems unproblematic in Lyon. In chapter 5, the Lyon public lighting network was described as *cohesive*—as well established and politically unproblematic. The DEP plays a crucial role within the city and contributes significantly to the City of Light's image in the international lighting scene, not only because DEP engineers help organise the Fête des Lumières but also because they actively engage in professional and political debates about urban lighting issues and light planning. The DEP is highly esteemed by both local and international lighting professionals. Its budget is stable and its work is supported by the Lyon administration, the mayor and his government. This was also acknowledged by an external committee that evaluated the Lyon's sustainable public lighting practice. The experts in question noted that Lyon's light policy was well integrated: According to them it is known by 'all the relevant stakeholders, both within the city administration as outside.' Furthermore, they found that the 'Lyon lighting department also communicates with most of them on a high level.' They remarked critically that 'the communication with the stakeholders is often *only* on a high level and *only at the beginning* of projects…' (GOJA, 2011, pp. 8, my emphasis).[361]

[361] The experts conceded: 'The cooperation and communication is often not continued on a lower level or throughout the whole project realisation period. We have seen no evidence of a horizontal working structure.' (GOJA, 2011, p. 8).

This critique supports my thesis that the head DEP planners have the leverage to mobilise the entire urban public lighting network from the start of an installation project.

With regard to organisational aspects, the DEP's collaboration with its private contractors occurs in the context of years of good and trusting cooperation. 'We are partners, we enjoy working with them,' described an installer of his firm's relationship with the municipal client (NSR, 2011-11-29a). An installer explained that they could learn from the DEP's LED testing (2012-01-27). Several manufacturers' suggested that the DEP planners were demanding customers. On the other hand they have benefitted from Lyon's good reputation and visibility ever since the Lyon light policy was developed in 1989 (cf. Marescaux, 2002).

The DEP also gains organisational strength and competence by operating and maintaining the public lighting infrastructures in-house. The fact that planning and maintenance are managed within the same organisation facilitates the exchange of information and experiences and gives them the opportunity to address technical problems or ask questions over a cup of coffee, as I myself experienced (NSR, 2011-12-02a). The maintenance unit is familiar with the lighting equipment on the streets and regularly communicates with the installation firms (NSR, 2011-12-01; product manager, 2013-10-04; lighting installer, 2012-01-27). Any technical or organisational problems that arise with new equipment—including LED technology—are internally discussed in team meetings or addressed in problem-oriented training sessions for DEP employees (2012-01-06). For instance, they are trained in how to handle LED technology, light control systems and other new technical equipment. In 30- to 60-minute seminars they discuss how to deal with broken LED components like drivers. The meetings are held 'on demand'.[362] For DEP employees, 'life-long learning' seems to be more than a catchphrase. The DEP management actively contributes to intra-organisational competence building. Because they are close to the street, they are aware of both local and global challenges ahead, including the disruptive nature of the LED business and the new skills required for it. 'You cut off a person from information for one year and … it's over', says a civil engineer (FD, 2012-01-06, pp. 1:02:10-01:03:50).[363] But while the technology is developing at high speed, the DEP employs electricians who have not changed job in forty years. Therefore, all DEP employees are expected to develop their skills.

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[362] An engineer joked that they would stop holding those seminars if LED technology stopped developing for one year. 'If we have nothing to say we won't assemble the people' (DEP lighting engineer, 2012-01-06).

[363] OV: *« Si vous coupez l'information d'une personne pendent un ans, elle est complétement… » NSR 'perdue'…engineer: C'est fini, quoi»* (DEP lighting engineer, 2012-01-06).

The DEP has also acknowledged the need for additional training in the field of electronics and LED technology (DEP head of maintenance, 2012-01-18). In this regard, they have taken a number of steps. They talk with and invite manufacturers to train the DEP staff. They also discuss education curricula with the educational institutions in the region and support vocational training for future lighting professionals.[364] These educational initiatives aim to ensure that Lyon can deliver a high-quality public lighting service run by well-trained personnel. When the first LED luminaires where installed in 2011, the head of the maintenance department assigned two 'LED deputies' to observe and collect information on the performance and characteristics of the new electronic equipment.[365]

Last but not least, we have seen that the public lighting infrastructures in Lyon are in good condition and are hence quite reliable. When failures are reported, the response time is a maximum of 24 hours. The international experts who evaluated the DEP's work reported seeing 'hardly any broken lamps' (GOJA, 2011, p. 5).

I conclude that the DEP has been able to rely on existing heterogeneous relationships. Even the collaboration with external lighting designers is well established and a part of the city's lighting policy (Marescaux, 2002). The routine interaction between actors from different professional backgrounds, the political standing of the DEP and the social acceptance of their public lighting service puts the Lyon light planners in a situation that gives them space for exploration. The situation could not be more different in the German capital.

The dispersed Berlin public lighting network

In Berlin, public lighting is a problematic public issue and the urban public lighting network is politically and organisationally *dispersed*. The municipal public lighting team seems caught between the Senate's austerity policies and the private light manager's interests. In contrast to their self-confident colleagues in Lyon, they gave a disillusioned account of their capacity to mobilise their public and private partners, including their superiors in the administration,

[364] There are few schools that offer training for light professionals and there is a common perception that engineering schools do not provide a sound professional training in lighting (NSR, 2012-01-25; (DEP head of maintenance 2012-01-18; DEP lighting engineer, 2012-01-06). The DEP director also taught lighting courses in a polytechnic school and keept sharing his expertise even after his retirement in summer 2012.

[365] When my research stay in Lyon ended in the beginning of February 2012, they had not yet taken up their work so that I was told that they would not be able to tell me 'grande chose'. Another employee argued that it was not necessary to assign people to collect information for the maintenance department, which the planning office already held due to their considerations and conversations in the planning process (NSR, 2013-09-19).

policy makers, the Berlin light manager and the ‘legions’ of subcontractors. The fact that the outdated infrastructure was in bad shape and needed modernisation opened the black-box of public lighting: Citizens complained about broken lights, gaslight amateurs protested, the Berlin parliament was divided. The problematic issue of infrastructural modernisation has mobilised an ‘issue public’ (Marres, 2007) that has criticised the municipal public lighting service. In 2013, the situation was so politicised that political actors represented SenStadtUm in public debates while the civil engineers were asked to not directly interact with their lay audiences. ‘We are not allowed anymore to make public statements’, said the head of the public lighting team in 2013 (NSR, 2013-07-31).

In addition to that, the municipal team’s competences are dispersed within the local administrative system due to austerity policies, administrative reforms, outsourcing and conflicting administrative interests. Since reunification, the public lighting team’s size has been reduced from 25 to six civil servants. In the course of a district reform in 2001, the administrative responsibility was transferred to the Mitte district; however, it was handed back to the Senate Administration in 2006. In 2013, all departments were asked to make submissions on which 25 per cent of their work were dispensable with the aim of cutting administrative staffing levels by 15 per cent (NSR, 2013-05-29).

The 2011 Berlin light plan was meant to coordinate and homogenise light planning practice on the district and state level, while also offering guidelines for the modernisation of Berlin’s lighting infrastructures. Yet as outlined above (5.3.2), the private light manager expressed a desire to replace all inefficient white lights with yellow sodium lamps, which is incompatible with the municipal quality criteria as outlined in the light plan. Since the firm had counted on getting a return on investment, it might demand compensation from Land Berlin. In addition to that, the status of the administrative implementation regulation, which is part of the 2011 Berlin light plan (SenStadtUm, 2011), is disputed. The regulation is based on the principle of ‘appropriateness’. However, the question of what *is* appropriate street lighting for Berlin was answered by an expert panel consisting of SenStadtUm representatives and lighting designers who made site visits to a number of streets. Lighting engineers, who believe in their professional standards and the EN 13201, do not agree with this method and criticise it as non-scientific and risky in terms of traffic safety. They are also the ones who usually plan lighting for SenStadtUm or the districts (Berlin lighting engineer, 2012-12-13).

Thus, and unlike Lyon, the collaboration within the public-private partnership is marked by diverging interests, underfunding, extensive restructuring and controversial modernisation activities. There is no shared future vision for Berlin's public lighting. The municipal lighting strategy is not (yet) supported by all actors in Berlin's public lighting network. Many of the key actors of the Berlin public lighting network used to work for Bewag before the reunification and reminisce about the good old times and the Bewag 'all-round carefree package'. Now, Land Berlin has put together the cheapest possible 'package-deal', based on the advice of external consultants. The new 'package' is all but 'all-round carefree' and instead reveals the heterogeneous interests of the public and private partners. Negotiations about what is in the package have overshadowed professional discussions on what is good public lighting.

The problems of the privatisation and restructuration also seem to impede the individual and mutual learning and knowledge flows that are so important for innovation. Competences and information are distributed in a network of municipal, commercial and scientific actors and departments. The six civil engineers in the public lighting team have no professional background in lighting engineering.[366] In the public procurement process and in the context of technological innovation they rely on external information and technical know-how.[367] The head of the public lighting unit describes the Berlin model as 'really unique' and 'an excess' of outsourcing (SenStadtUm civil engineers, 2012-12-05).[368] In contrast to other cities, SenStadtUm has no immediate contact with service and installing teams and hence does not receive direct feedback. They point to the situation in Hannover. There, the municipal developer has a team in the field.

> 'He says he lives on sending his people out in the morning and then they come back in the afternoon and tell him about the new equipment and the problems on the street. […] Here you

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[366] OV: *„Also wir haben keinen Lichtplaner hier bei uns. Keinen. Also wir haben lauter Kollegen, die Interesse am Licht haben, sich in diese Materie einarbeiten aber wir haben keinen, der das prüfen könnte. Wir kennen die Leuchtmittel, wir kennen die Leuchten"* (SenStadtUm civil engineers, 2012-12-05).

[367] Light technological expertise is represented by actors from science and industry—the private light manager and energy supplier, local light manufacturing and installer firms and the optical and light technological departments in Berlin Universities, notably the Technical University of Berlin (TUB).

[368] OV: *„Von der Organisation find ich uns nun schon wirklich speziell. wenn man vielleicht den Abfahrdienst bei uns selber hätte oder irgendwie drei Leute, die an Beleuchtungsanlagen auch mal was dranschrauben könnten in schlimmen Fällen. Oder wenn Sie eine Truppe haben, die einen bestimmten Teil dieser Leistung selber macht, um nicht diese Abhängigkeit durch diese Dreistufigkeit zu haben. Also das ist in Berlin wirklich schon wie ein Exzess, was wir hier veranstalten"* (SenStadtUm civil engineers, 2012-12-05).

really depend on people that still talk to us and drive with open eyes to the nocturnal city' (SenStadtUm civil engineers, 2012-12-05).[369]

Apparently, the relationship with the private manager does not permit an open knowledge exchange. SenStadtUm therefore keeps in touch with subcontractors for first-hand information from the street.[370] 'We invite them or call them,' explained the director of the public lighting unit.

> 'But we have the problem that [the manager] is their direct client. Normally, they have to discuss their problems with [the manager]. And if [the manager] decides "you only talk with us and not with the Senate"… Then they really do not talk to us. And that really means you learn about many things only months or weeks later, or not at all, or filtered'[371] (SenStadtUm civil engineers, 2012-12-05).

In interviews and conversations, public lighting team members sometimes seemed demoralised.[372] Their hands are tied due to budget freezes, downsizing and legal or administrative problems. At the same time, they are under pressure to modernise the outdated infrastructure, which has deteriorated in the course of the restructuring and privatisation process. According to the new manager, there were 20,000 failure and trouble reports in 2011 and more than 1,000 cases of old damage (head light manager; 2013-06-10).

In this situation the municipal team is not in a position to experiment, or to try and speak for new approaches and innovation. As team members report, one argument against the LED experiment in Leibnizstraße was that it seemed already impossible to manage and maintain existing installations properly.

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[369] OV: *„Der sagt, er lebt davon dass er morgens die Leute losschickt und dann kommen die mittags wieder rein und erzählen ihm wie das neue Material ist, was es für Probleme auf der Straße gibt. So—Das ist ja bei uns alles nicht. Sie sind hier wirklich davon abhängig, dass Sie Leute haben, die noch mit uns reden und die mit offenem Auge durch die nächtliche Stadt fahren"* (SenStadtUm civil engineers, 2012-12-05).

[370] OV: *„Das ist der Nachteil, […] also diese Hierarchie. Wir haben das Problem, wir erfahren viele Dinge erst, wenn wir mit den Nachunternehmern reden, weil [der Lichtmanager] es entweder auch nicht weiß oder uns nicht erzählt. Also diese extreme Teilung die wir hier machen, die ist schon…speziell"* (SenStadtUm civil engineers, 2012-12-05).

[371] OV: *„Wir laden die ein, oder wir rufen die an. Wir haben aber das Problem, [der Manager] ist ja direkter Auftraggeber, normalerweise müssten die all ihre Sorgen mit [dem Manager] besprechen. Und wenn [der] dann festlegt, ihr redet aber nur mit uns und nicht mit dem Senat. […] Dann reden die wirklich nicht mit uns. Und das heißt dann wirklich, Sie erfahren viele Dinge erst Monate oder Wochen später oder gar nicht, oder gefiltert"* (SenStadtUm civil engineers, 2012-12-05).

[372] From my field notes: A civil engineer who was among the last to join the team indicates that his colleagues either lack the motivation, the nerves or the social skill to do their job effectively. One colleague knows the existing equipment and infrastructure perfectly well but does not keep up with the technical change. 'He is stuck in the 1990s state of the art.' He adds that their job is really not that difficult. The planning and calculations are done by others. The SenStadtUm team's job is to talk to people, to go and check and to manage the processes.

I conclude that the public lighting situation in Berlin is presently not very innovation-friendly. The existing network of actors and things is characterised by heterogeneous interests and incompatibilities. SenStadtUm is confronted with post-unification organisational problems and a public-private package deal that is not carefree but requires renegotiation. At the present moment, it is hard to tell whether the working relationships between SenStadtUm and its light manager will develop and stabilise in the course of the seven-year contract (2011 to 2018). The head of the management team speaks of initial 'friction losses' (2013-06-10). Furthermore, it remains to be seen how effective the Berlin light plan will be in coordinating the cooperation between the Land and the districts. What we can concede is that at the point in time when LED technology was new and ready to be tested, the Berlin public lighting network had more pressing problems than innovation. Outdated infrastructure is a major Berlin-specific problem, which cause public resentment and call for modernisation strategies that are controversial among experts and cause political protest. Thus, the political climate does not leave much space for trial and error. 'You are not allowed to make mistakes,' said a civil engineer (AT & AK, 2012-12-11). Instead, the public lighting team has to prove and justify its work and decisions in public—in front of policy-makers, other departments or gaslight amateurs. In the face of an existing and problematic heterogeneity, it seems more opportune to *show* things that work than to *test* new technology.

Looking at Lyon, we see a very different situation. The functioning urban public lighting network opens up spaces for innovation. Its strong and unquestioned role as a pioneer in lighting puts the DEP in a resource-rich situation. The municipal lighting strategy is widely accepted and even highlighted as a shining example and does not have to be defended in public trials. DEP planners know and need not test their private partners. Thus, they can concentrate on their lighting duties and competence building.

7.3.2 City-specific LED configurations

From a global perspective, the early public LED installations in Lyon and Berlin were carried out in similar situations. In 2011 and 2012, the LED luminaires on the market for street lighting had already passed their first real-life trials but still prompted uncertainties among their users (4.2.2). Furthermore, climate change mitigation policies, the EU Ecodesign directive and the European Standard EN 13201 affected both cities, even if the national implementations vary in France and Germany. As a result, Berlin and Lyon were confronted with similar challenges, namely to modernise their urban lighting infrastructures in order to reduce their energy consumption in public lighting and to replace all their HPM luminaires before the light source disappeared from the market. Yet despite these similar global conditions, the local LED strategies varied considerably and the innovation was used and perceived differently in Berlin and Lyon. Again, we have to look at the urban situations in order to understand the different configurations.

In a nutshell, my observations show that the Lyon DEP installed *cutting-edge* LED solutions in order to develop its competence and assert its pioneering role in public lighting internationally. In contrast, SenStadtUm is more interested in *reassuring* LED solutions in order to modernise its lighting infrastructure *without* changing the urban image. The argument which I will develop is the following: The DEP tests what is technologically possible and socially acceptable as part of its engagement in global debates on innovation in urban lighting. In Berlin, the public lighting service is entangled in local debates and on trial. Its LED installations are political compromises between global energy-efficiency issues and local austerity policies, citizens' protest and preservationists' concerns. SenStadtUm adopts conservative technological approaches that are suited to depoliticising the local public lighting issues. In Berlin, technological innovation *preserves* the urban image, while in Lyon public lighting in general and the LED innovation in particular are a means of *regenerating* the urban image. Again, I start with Lyon.

Cutting-edge LED installations

The DEP engineers share the global fascination for LED lighting:

> 'LED surprises us every day because it evolves so quickly that... it can only surprise us. Because... you receive a product, you install it and, before you take the measurements at the inauguration, the manufacturer tells you, "No, that's discontinued, there's a new one. We have a LED that illuminates thirty percent more, you have the old model." So, of course, we're surprised every day. We're surprised because we're learning. It's a great adventure that's constantly unfolding, a constant evolution, a constant learning process' (DEP lighting engineer, 2012-01-06).[373]

[373] OV: *« La LED est étonnant tous les jours. Parce-ce déjà elle évolue tellement vite…que… que.. elle ne peut que nous étonner. Parce-ce que…on vous livre un produit, vous l'installez sans [que] vous avez fait les mesures à l'inauguration le fabricant va vous dire : a, mais non, ça on a arrêté, on a un nouveau. On a une LED qui*

Nevertheless, the Lyon DEP planners are renowned for their 'prudent', even 'too prudent' attitude towards the new LED technology (lighting consultant, 2012-01-11).[374] Asked about his Lyon clients, a manufacturer explained that 'they are bound to be exigent' since Lyon receives a lot of public attention.

> 'They don't want to be deceived. They want to be sure that everything works […] because if not this could have delicate consequences for their media coverage. They are prudent and in this sense a little bit more pedantic, or a little bit more complicated than the others' (Product manager, 2013-10-04, my translation).[375]

At the same time, the positive international appeal of the 'true City of Light' not only confirms the merits of local light policy but also enables and motivates the municipal engineers to keep their pioneering role and stay ahead of things—'to take things further', as I have often heard.

By *testing* the technology, the 'prudent' DEP engineers are able to partake in the 'revolution' without risking their political standing in Lyon and their reputation in the world.[376] Since 2011, the municipal engineers have installed the innovation not only in the three above-described cases but also in a number of other projects. In all of these projects, the DEP is cautiously exploring the state of the art in LED lighting and is trying to make the most of the new technology. As we have seen, the dimming option was successfully implemented and tested on Place Bellecour. In Montée du Boulevard the DEP tested the operability of an innovative LED fixture. In Rue de l'Oiseau Blanc and Rue Thénard they explored how they could maximise homogeneity despite large pole distances, while minimising energy consumption and stray light on facades. They also installed dimmable LED lights and sensors on a small pedestrian bridge for a test with presence detection. In a more recent project the DEP is also testing presence-control systems in a Lyon neighbourhood (NSR, 2013-09-19).

éclaire trente pourcent plus. Vous avez un ancien model. Donc, forcement on est étonné tous les jours. On est étonné parce-ce que on découvre. C'est une grande aventure qui se passe. On continue une évolution permanente une remise en question » (DEP lighting engineer, 2012-01-06)

[374] OV : *« Souvent les gens disent ils [DEP] sont trop prudent. ... Tellement parce que… Les fabricants, ils ne peuvent pas vendre tous ce qu'ils veulent vendre. Parce que […] le patron, il est ancien. Il a de la bouteille* comme on dit en français, il est ancien, il a de l'expérience, donc il est très très prudent»* (Lighting consultant, 2012-01-11) *Être expérimenté, avoir de l'expérience avec l'âge.

[375] OV : *« Ils sont forcément plus exigeants. Parce-ce que effectivement, comme il y a cette approche médiatique ils ne veulent pas tromper. Ils veulent être sure que tout fonctionne et que les options, les choix qu'ils auront fait fonctionneront parce que si no ça pourrait avoir de retombées médiatiques délicates. […] Ils sont prudents. Et c'est dans ce sens là, ils sont un petit plus pointilleux, ou un petit peu plus compliqué que les autre. Mais ça se peut comprendre»* (Product manager, 2013-10-04).

[376] In 2011 and early 2012 they acknowledged the technology's great potential but found that conventional technologies were still comparably effective and more reliable (FD, 2012-01-06; NSR, 2013-09-19).

The key objective of all these ‘experimental installations’[377] is to save energy without compromising on the good quality of street lighting and without giving the impression that the City of Light has reduced its light levels. In this respect, LED technology offers them the opportunity to explore innovative approaches that comparatively efficient conventional light sources like high-pressure sodium cannot offer: With LEDs they can steplessly dim and reduce light levels temporarily during the calm hours of the night or install presence detectors so that the light levels are very low as long as nobody is on the street. All these public tests are in line with current expert discussions on sustainable lighting. In conferences, new possibilities and approaches offered by adaptive lighting are often described with the catchy phrase ‘light where and when needed’ (LUCI, 2012b; NSR, 2013-09-18/19/20/21).

But the DEP’s explorative engagement in LED activities does not stand alone. It is part of the DEP’s more general strategy of experimentation and professional training (Ville de Lyon, 2004). Eager to maintain their competence, DEP employees seem to constantly seek new challenges. ‘We test’ was a statement I heard quite frequently when talking to DEP staff about their work (DEP lighting engineer, 2012-01-06; NSR, 2012-01-31). This attitude is reflected in the DEP’s approach to LED lighting as well as in other experimental activities in the course of the Fête des Lumières and the EVALUM.

The Fête des Lumières offers the DEP a temporal space in which they can explore new creative ways of illuminating the city. Each year, the DEP actively contributes to the festival with one artistic light show or installation. The planners describe their festival practice as creative ‘bricolage’ (NSR, 2011-12-02b). Nothing is impossible around the 8th of December, when the event takes place. The festival offers DEP employees the opportunity to ‘do things differently’. If they adhered to all rules, they say, they could not create such a festival. The DEP director concludes that the DEP employees’ attitude differs from what one usually finds among civil servants (NSR, 2011-12-02b).[378] As a temporal space for experimentation, the festival complements the DEP’s perennial explorative engagement with city lights well. The festival also offers them the chance to create and display light installations that are at once

[377] As outlined above, a DEP planner explained their approach as follows: ‘An experiment is the real thing because, for us, when we experiment... often we leave them in place, to see how long they last. So it’s the real thing. It’s an installation. We call it an experimental installation because it’s different than the majority of what we do’ (DEP lighting engineer, 2012-01-06).

[378] I imagine the festival as a kind of team-building event. This description parallels my impression. Sneaking around on the DEP premises, I met several workers who were busy preparing for the Fête des Lumières. They seemed motivated and positive about the project. Although the Lyon public lighting experts do not use the festival equipment for lighting streets, they feel challenged and motivated by this exceptional task (NSR, 2011-11-15; NSR, 2011-12-02a; Schulte-Römer, 2013b).

acknowledged and admired by festival visitors and citizens (cf. Schulte-Römer, 2011-12-10). But feedback from citizens is not just important in the context of the annual event but also in the context of LED installations, which brings us to another experimental format, the EVALUM series (see 5.4.1):

> 'The novelty of the EVALUM […] is that we have the population test it [lighting technology]. And it's the population that tells us, "I need this," which is much more interesting, because they're the final client. […] with these notions of ambiance and safety, it's always better when the population weighs in. Because we can sometimes have preconceived notions. Sometimes we think one thing, but with our technical, expert opinion we can sometimes be wrong, or mistaken, because we're too technical, our vision is too narrow, we're too involved in the business, I'd say. So here, at least, the final client, the population weighs in and says "I prefer this, I need that." And that way we can tailor our offering without a go-between. So that was the novelty of the EVALUMs' (DEP lighting engineer, 2012-01-06).[379]

Thanks to the EVALUM but also thanks to their experience, the DEP planners have an idea what kind of lighting is socially acceptable in Lyon. Indeed, the Lyon LED installations, including the dimmed lights on Place Bellecour and the new and brighter lights in Montée du Boulevard, did not provoke any significant reactions. For DEP planners this is not surprising. They are convinced that the citizens *'don't care'–« ils s'en foutent »* (NSR, 2012-01-31).[380] My conversations with Lyon's citizens support the professionals' experience in the sense that Lyon residents engaged with the issue of public lighting either subjectively ('our street is brighter and better lit') on a very general level, mostly in favour of energy efficiency.

I conclude that citizens did not play an active role as observers of the above-described early public LED installations. Introducing LED lighting in Lyon meant installing, using and thereby testing the technological innovation in front of expert observers. It also allowed actors from the public lighting network to gain experience with the new technology under real-life

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[379] OV: *« Par contre, pour ces notions des ambiances et de sécurité c'est toujours mieux que ce soit la population que s'exprime. Parce-que nous, on peut d'ailleurs avoir des idées reçues, des fois on estime …des choses. Mais avec notre avis de technicien et d'expert on peut être… par fois … dans le faut, dans l'erreur parce-ce qu'on est trop dans la technique, trop dans le métier je dirais. Donc là, au moins, le client final, la population s'exprime et dit « moi, je préfère ça, j'ai besoin de ça. Et comme ça on peut répondre directement au besoin sans intermédia. Donc, c'était un peu ce qui était nouveau avec les EVALUMs »* (DEP lighting engineer, 2012-01-06).

[380] Again, the DEP's efforts in eliciting citizen feedback are in line with wider expert discourses, especially issues of place-making, urban regeneration and *social* sustainability (Schulte-Römer, 2010). Yet, an expert committee found that the City of Lyon could do more in this respect: 'We miss your constant and equal dialogue with the citizens, the final end users of your services. Although your goal is to deliver high quality services to the population of Lyon, you have no structural feedback from your main target group' (GOJA, 2011, p. 8).

conditions and to develop their professional competence. In the face of technological change and Lyon's energy reduction targets, the DEP is systematically exploring the advantages and limitations of LED lighting in order to stay ahead of technological developments and expert discourses. By trying out innovations they simultaneously test their professional capacity to provide state-of-the-art efficient and innovative lighting solutions. In Lyon, LED lighting is perceived and installed *in line with* global discourses or 'imaginaries' (Suchman, 2012), as an energy efficient, maintenance-friendly flexible technology that was already able to offer the best technical lighting solution as early as 2011, provided it was thoroughly tested and carefully applied.

Reassuring LED installations

Again, the situation was very different in Berlin. In Leibnizstraße, the public lighting team showed an interest in LED lighting but they did not have the resources to explore the innovation as a cutting-edge technology. On a more general level, we have already seen that the politicised situation was not favourable for technological experimentation, which is also reflected in Berlin's public procurement practices. In order to specify products for procurement, SenStadtUm relies on the expertise of its private light manager. Yet the manager's criteria do not necessarily comply with the Senate Administration's urban design criteria. Furthermore, SenStadtUm is controlled by a centralised public procurement department, which the head of public lighting described as 'uniquely' strict (NSR, 2013-05-22). Lighting experts almost unanimously complain that the procurers rank economic criteria over the quality of light (NSR & Toschka, 2013-05-29).[381]

In addition to that, the light manager is opposed to installing expensive LED luminaires, not only because its maintenance advantages are not yet proven but also because the contract incentivises the firm to install the most efficient and also cheapest lighting equipment.[382] As a

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[381] OV: *„Wir sind an wirtschaftliche Ausschreibungen gebunden. Das ist doch in Berlin so, wir sind fast die obersten Wettbewerbshüter von ganz Deutschland. In Berlin wird alles ausgeschrieben und der Billigste bekommt es. nicht der Wirtschaftlichste, der Billigste. Und dann hat man irgendwelche Leuchten. das Einzige was wir vielleicht durchsetzen können ist, dass das Licht weiß bleibt und das keine NAV [Natrium-Hochdruck] Leuchte installiert wird"* (SenStadtUm engineer, 2012-12-11).

[382] SenStadtUm employee: *„Also [der Lichtmanager] hat das Ziel Energie zu sparen und das mit ganz kostengünstigen und wartungsarmen Leuchten und Leuchtmitteln. In diese Zusatzvergütung die [der Lichtmanger] bekommt fließt der Preis für die neue Leuchte ein. Je teurer die neue Leuchte ist, da ist es ganz egal, wie viel Energie wir mit der neuen Leuchte sparen, umso niedriger fällt die Zusatzvergütung [für ihn] aus. Das heißt, [der Lichtmanager] hat kein Interesse LED-Leuchten einzusetzen"* (SenStadtUm civil engineers, 2012-12-05).

result, there is so far only one use of LED lighting that justifies the high investment, namely LED technology as a solution to the gas-light problem. The LED retrofit approach exemplifies Berlin's city-specific LED configuration.

What makes this configuration particular is that lay audiences are actively involved in its enactment. In the context of the heated debate on the Berlin gaslights, LED technology was first 'imagined' as a technological solution to a local political conflict. As the minutes of the Berlin Parliament show, the LED compromise was long awaited and envisioned as a means of preserving the 'historic' pole-top gas lanterns in residential areas (Abgeordnetenhaus Berlin, 2011-06-23). Furthermore, a little anecdote shows that Berlin citizens did not just engage passively with LED lighting, but also spoke publically for the technological innovation: During a public debate in Charlottenburg, where the pro-gas-light coalition is strong and gas-alignment luminaires were due to be replaced, citizens strongly opposed the replacement with the luminaire *Jessica* because of its cool-white fluorescent light and called for LEDs instead (NSR, 2012-08-21). Yet it was too late—or too early: SenStadtUm had procured the fluorescent luminaire from a Berlin-based manufacturer at a time when LED technology was not yet a feasible solution for the illumination of main streets (NSR, 2010-09-21). Today, the manufacturer also offers LED versions of the luminaire, which are of course more expensive.[383]

However, in terms of 'global' innovation criteria like cost and energy efficiency, as are typical for the 'industrial world of worth' (Boltanski & Thévenot, 1991), the Berlin LED configuration appears less appealing. Lighting engineers contended that the new technology could be used more efficiently. The LED lights in Saalestraße and Falckensteinstraße mimic gaslights in colour and light distribution. Like the gas lanterns, they shed light not only on the street but also on the house facades. As a result, one of the greatest advantages of LED technology in terms of energy efficiency is intentionally compromised, namely the possibility to direct the light to where it is needed on the street. In addition to that, warm-coloured LEDs consume more energy than cool-white diodes. The customised Berlin LED retrofits thus explicitly respond to local needs and partly compromise the global promise of LED lighting as an intelligent 'no-brainer' (cf. European Commission, 2011-12-15a).

[383]Paradoxically, Berlin citizens associated the LED retrofits with warm-white light whereas the more general public perception of LED light is still marked by the experience of the first cool-white LED installations. Although most cities today, including Lyon and Berlin, install LED lighting with neutral or warm-white colour temperatures most laypeople I talked to thought that LEDs gave a rather unpleasant 'cold' light.

This interpretation of the Berlin retrofit approach also holds when we look at the two remaining LED cases. In Leibnizstraße, SenStadtUm had planned to install dimmable state-of-the-art LED technology. However, the project planners were not successful in creating a 'configuration that worked' *for Berlin* (Rip & Kemp, 1998, p. 30). The telemanagement system was considered too expensive and incompatible with existing light management routines. Energy savings could not be exploited financially and although residents were rather content with the new lights (Besecke & Hänsch, 2015), the project was considered a failure.

Finally, the LED presentation in Altonaer Straße also supports my thesis that Berlin sought reassuring LED configuration: The luminaires presented were designed to mimic the existing linear luminaires in shape and light colour—in line with the Berlin light plan that aims to preserve the Berlin city image including its 'typical' luminaire designs (SenStadtUm, 2011). The lighting designer even implicitly made excuses for the fact that the LED cases were shorter than the original luminaires, which had long fluorescent tubes: He justified the modification with reference to a 'green' argument (cf. Thévenot, 2002) and explained that the more compact design would reduce both the cost of materials and the carbon footprint of the luminaire in a cradle-to-grave analysis. He thereby mobilised an argument that is relevant in the context of 'green public procurement'. The Berlin Senate Administration only adopted the EU recommendations for 'green public procurement' in October 2012 in the form of a new administrative regulation that obligates SenStadtUm to consider the energy consumption and full life cycle of electrical equipment like lighting technology (SenStadtUm IX B 22, 2012-10-23). The public lighting team did not seem particularly fond of having to adhere to yet another administrational rule.

I conclude that the Berlin LED configuration enacts LED technology as an innovation that is new and better because it is modern, less failure-prone and energy efficient but still looks familiar, mimics the existing luminaires and does not change the look and feel of Berlin's urban spaces. The reassuring LED configuration offers a technological solution to a specific political problem, namely the gaslight conflict, because it renders the withdrawal of the beloved technology invisible. In this respect, the LED retrofits might contribute to turning Pandora 's Box back into the black box that public lighting usually is in contemporary cities.

So far, the reassuring LED configuration is the only LED solution that has worked for Berlin. More radical 'intelligent' configurations of the kind tested in Lyon seem incompatible with the existing socio-material network and are also not affordable.

Finally, these findings allow me to reconsider the question of the political visibility of pilot projects. While the literature on state-funded innovation projects suggests that political visibility jeopardises their success (see 2.2.1), my observations suggest that political visibility creates a city-specific 'climate' for the development of urban configurations of innovations. As we have seen, the Lyon LED configuration is closely linked to the positive image of the local light policy and Lyon's image as 'City of Light'. Similarly, the politicised situation in the 'Gasopolis' created a window of opportunity for LED lighting. To the present day, only gaslight refurbishments justify the investment in comparatively expensive LED technology. When it comes to standard refurbishments, the private light manager opposes the implementation of the innovation.

7.3.3 Spreading the word: City-specific publics for urban lighting

This last finding of my analysis is highly relevant for those who are interested in the 'diffusion success' of 'early public LED installations'. As outlined above, I found that the 'world of lighting' acknowledged the early public LED installations in Lyon but took little note of what is going on in the German capital. The Berlin projects are known to the local urban public lighting network and the pro-gaslight alliance. The Lyon LED experiences are widely communicated. This is not surprising if we once again compare the public lighting networks in Lyon and Berlin. This time, the focus is not so much on their quality but on their scope. I will show that the exchange of experiences and distribution of information is easier in Lyon since the respective platforms and channels are already established in a public lighting network that is both cohesive and expansive. In this respect, the Berlin public for urban lighting seems rather self-focussed. Yet that is not all.

As we have learned from Mangematin and Callon (1995), first or early users are also representative of future users of a new technology. Again, the Berlin reassuring LED configuration appears less representative and hence less interesting for potential imitators. Lyon, on the contrary, is highly esteemed as a pioneer and the DEP actively exchanges information and experience with its peers and also with industrial partners.

An expansive pôle de compétence

With regard to peer-to-peer exchange, the Lyon lighting engineers share their professional experience with fellow civil engineers, other cities and educational institutions. As outlined in chapter 5, these platforms have been actively created by the City of Lyon. The regional meetings of the *Association des Ingénieurs Territoriaux de France* (AITF), which offer civil engineers the opportunity to exchange with their colleagues, are one example of this. During a one-day gathering, which I attended in January 2012 and which was chaired by the DEP, the municipal actors also discussed current political, legal, economic and technological developments, including their experiences with LED technology. The DEP had even invited a manufacturer to present a customised LED retrofit solution developed for one of the most widely used street lanterns in Lyon.[384] Thus, these meetings offer municipal lighting experts an overview of what is possible with new technologies and information on non-technical developments, like new climate change policies or initiatives against light pollution, which were at issue in France at the time (ministerial consultant, 2012-02-02 #2089).[385]

In addition to these professional exchanges among civil engineers, the DEP is also actively involved in transdisciplinary expert exchange on urban light planning within the city network LUCI. DEP representatives regularly attend 'City under Microscope' events and meetings of the LUCI steering committee. They also participated in a number of innovation-oriented projects like the PLUS project and the LUCI charta on urban lighting, which promotes a 'culture of sustainability'.[386]

In addition to that, the Fête des Lumières functions as a hub for expert interaction and networking. Lyon-based institutions like LUCI or the Cluster Lumière organise conferences and receptions for their members and sponsors (NSR, 2011-12-06 2011-12-09b, 2011-12-09c). Thus, the festival of light not only fulfils an important city marketing function but also constitutes a forum for transdisciplinary knowledge and information exchange among light professionals. As we have seen, site visits to Montée du Boulevard and Place Bellecour were organised during the festival, when the 'world of lighting' meets in Lyon.

[384] The objective was to optimise its light distribution and render it more efficient with LEDs (NSR, 2012-01-25).
[385] During the negotiation and solicitation process, the French Minister for the Environment also consulted the Lyon DEP in order to get their expert opinion on light pollution (NSR, 2011-12-02b).The French law against light nuisance was passed in 2013 (cf. Morgan-Taylor, 2015).
[386] http://www.luciassociation.org/luci-charter-on-urban-lighting.html, last access 2014-08-29.

Finally, the DEP also shares its experience in practical more pervasive ways. As mentioned above, the DEP has founded a private organization which allows them to plan lighting projects in partner cities all over the world (5.), including Vietnam, Russia, Havana, Algeria and Germany. If the customs regulations of the partner country permit it, the DEP will be able to import both their professional know-how and also their trusted lighting equipment, which makes their international activities interesting for the French lighting industry.[387]. 'You always learn and you call into question what you do', comments a DEP planner on his experiences abroad (NSR, 2013-09-19). Lighting equipment performs differently in the Algerian desert and in Russia due to the climatic conditions.[388]

We can conclude that the City of Light receives international attention in the 'world of lighting', which has made it easy for its commercial partners to raise interest in Lyon's early public LED installations, especially as the installations have been well executed. In addition to that, Lyon is also '*representative'* for a number of other progressive potential municipal LED users (Mangematin & Callon, 1995). The City of Light is part of a transdisciplinary and international expert network—a 'network' in the conventional sense—that includes industrial actors, policy makers, researchers and scientists as well as municipal lighting professionals, urban planners, consultants and lighting designers. The network has also developed and is still developing around issues of urban lighting. The key issues are sustainability, city marketing and how to provide efficient high-quality lighting 'where and when needed'. Thanks to its explorative approach and commitment, Lyon plays a role and contributes to debates on both urban regeneration and sustainable lighting. In the context of the LED innovation, the DEP planners thus play a dual role: They are renowned as prudent *users* of innovation and therefore, just like the early 18th century gentlemen (cf. Shapin, 1988), they have the social credibility to verify innovators' claims about their new solutions. On the other hand, the Lyon civil engineers *are also being observed* by others as they try new approaches and test site-specific LED solutions. In this respect, their light planning can also be considered an innovation. It was recognised as such and positively evaluated by observers and has also found a number of imitators world-wide (Gonzalez, 2010).

[387]If they cannot bring the technology they know, projects become tricky, explained the DEP director. In Algeria, for instance, they insisted on their own, 'copied' equipment which was also low quality (2012-01-25). The planners consider these projects not only an export of expertise but also a learning opportunity. Like the Fête des Lumières, the projects challenge them to break their daily routines and thus add to their professional competence

[388] Local installing firms work differently and sometimes have to be trained to be able to do the maintenance.

A self-referential 'unique place'

Not surprisingly, Berlin's LED configuration corresponds less to global problems and needs. As we have seen, it offers a compromise that preserves a 'unique' urban atmosphere, as the gaslight amateurs described it. There is no city anywhere else in the world with a similarly extensive gaslight challenge. [389] The city-specific LED retrofit solution is therefore rather marginal in global discourses on urban lighting and LED development. In public lighting, Berlin seems not to play a leading role in Germany. Even if one of the municipal interviewees suggested that Berlin was still 'doing quite well' when compared to other cities and could still set an example, as it did in the Bewag era, the focus of attention in the 'world of lighting' seems elsewhere: Hannover is famous for its LED tests, the cities and communes who participated in the competitive BMBF programme for LED lighting (*'Kommunen in neuem Licht')* received a lot of attention, cities like Stuttgart and Augsburg are also renowned for their expertise in public lighting.

If we compare the Berlin situation to Lyon, we find that the investment backlog and chronic underfunding are not the only reasons. Instead, Berlin public lighting practice is marked by explicit local references and coupled with a lack of international relations. The combination makes it difficult to perceive Berlin as a shining example, although the Berlin light policy can also be considered original, in the sense that it integrates and recombines global, urban and local objectives in a comprehensive strategy. Yet goal-oriented as it is, the Berlin light plan is less suited for international imitation than the 'pragmatic' policy-oriented Lyon light policy. The Berlin light plan offers a city-specific strategy rather than a new urban planning approach. It is based on Berlin-specific expert evaluations and celebrates the comparatively low light levels in the city as 'typical' for Berlin ('Berlin is dark and should remain that way…').[390] But there are more structural than programmatic reasons for this want of exchange.

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[389] There are still several cities that have some gaslights, for instance Leipzig, Frankfurt am Main or Düsseldorf, where citizens also protested against the municipal electrification plans. In addition to the public lights, there are also still private users of gas lanterns. It is nevertheless a niche market.

[390] The municipal urban design team who initiated the light planning process showed little interest in exchanging with colleagues. In conversations and public presentations, they explicitly distanced themselves from the Lyon brightness (SenStadtUm urban designer, 2010-02-22; NSR, 2011-04). In 2009, SenStadtUm representatives went to Lyon and were awarded with a LUCI sustainability prize for their lighting strategy during the Fête des Lumières. [390] Yet retrospectively, the visit seems to have created more internal problems than networking opportunities.The trip prompted a debate on corruption within SenStadtUm because one of the civil servants who had travelled to the award ceremony in Lyon later felt that it had been inappropriate to do it on the expenses of a private sponsor. I have not come across any similar discussions in Lyon.

The Berlin civil engineers have few opportunities to exchange with colleagues from other cities. Since the SenStadtUm employees are not lighting engineers and do not manage the lights themselves they are also not part of the respective expert groups. A civil engineer who joined the public lighting team in 2008 states that he learned everything he knows from the private light manager. In stark contrast to their Lyon colleagues, the Berlin civil engineers describe a lack of resources for professional training. The unit's budget for training measures is calculated per employee. Yet the fees for expert conferences are high and exceed the training budget that is allocated per team member. Expert interactions takes place locally and sometimes bilaterally over the phone with familiar colleagues in other cities: If we see something we are interested in, we call [the colleagues in other cities] and exchange information somehow' (SenStadtUm civil engineers, 2012-12-05). There is also no equivalent to the French association of civil engineers AITF. Only the private light manager attends the meetings of the German public and private light operators (head light manager; 2013-06-10). Unlike their SenStadtUm colleagues in the urban design unit, the public lighting team showed an interest in more regular exchange. 'We have proposed several times that the cities could meet once or twice a year' reported a civil engineer and added that the suggestion was met with enthusiasm. But organising it proved 'problematic' as tax money could not be spent on joint meetings. They couldn't accept private sponsorship either (SenStadtUm civil engineers, 2012-12-05).[391]

In this situation, the SenStadtUm engineers attend the 'light technological colloquium', which is held monthly by the Berlin group of the German lighting society LiTG and hosted by the TUB lighting engineers. The colloquium offers both insights into state-of-the-art light technological issues[392] and a good opportunity to meet representatives of the Berlin lighting industry in an informal setting after the presentations (NSR, 2012-04-25, 2012-11-21, 2013-01-16).[393] The colloquium is also attended by commercial actors from the lighting industry

[391] Civil engineer*: „Wir haben jetzt schon ein paarmal vorgeschlagen und ist auch auf Begeisterung bei den anderen gestoßen, dass wir ein- oder zweimal im Jahr, dass die Städte sich mal treffen. aber wer soll das organisieren, wer hat Geld. Sponsoren dürfen wir nicht nehmen, das ist alles problematisch. man kann die Leute nicht einladen, von alleine dürfen die auch nicht kommen, es ist alles nicht so leicht"* (SenStadtUm civil engineers, 2012-12-05).

[392] Presentations I attended discussed trends exhibited at L+B, the gaslight replacement process, standardisation of light quality in work spaces, intelligent lighting systems, light technological evolution, and light festivals,…

[393] The event thus seems to play a field configuring role as it facilitates network formation, agenda setting and presents its attendees—including participant observers—the Berlin world of public lighting in a nutshell (seeGarud, 2008, p. xx).

and private service providers.[394] Yet in contrast to their Lyon colleagues, the Berlin civil engineers participate as silent spectators in these meetings. In other words, they act less like the kind of competent and critical observers that lend innovations their 'street credibility'.

We can conclude that the Lyon lighting practice and professional exchange, especially within the LUCI network, are taken into account by innovators and technology users on the national, EU and even *global* scale, while the Berlin activities are locally interesting, especially for the local small and medium-sized business partners and also for critical citizens.

In addition to that, the Lyon LED configuration is shaped by and hence resonates with the latest global technological knowledge in lighting engineering, and with discourses on sustainability and city marketing. The DEP's 'cutting-edge' early public installations are interesting for both future users of LED lighting and manufacturers or designers of LED solutions. One might say that what is considered 'new and better' in Lyon is in line with what is considered new and better by LED innovators all over the world.

Compared to Lyon, the Berlin LED configuration seems almost subversive in the sense that it does not follow the hegemonic vision and version of the innovation. Local controversies have encouraged *local* co-developments and a Berlin-specific retrofit solution. What Berlin's urban designers and preservationists consider 'new and better' does not correspond with the global 'imaginary' of 'intelligent LED lighting'. One could therefore argue that Berlin's city-specific solutions are not 'interesting' for international discussions and developments but speak to local problems. Hence, they are not communicated beyond the urban public lighting network.

One might critically remark that the global 'system of innovation' seems quite self-referential, too. It selects the information it needs to improve the lighting solutions it already produces. As a result, the global version of LED technology as a climate-saving 'no-brainer' is also reproduced. This brings us back to more general questions of innovation in our society today, which I will address in my conclusion.

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[394] I also met a SenStadtUm employee during a foundational meeting of the Berlin lighting cluster (NSR, 2013-01-25). The first meeting of the lighting section was initiated and organised in 2011 (OpTecBB, 2011-02-28) by a research fellow at the School of Business and Economics of the Free University Berlin together with the TUB lighting technology department. The economist had provided expert scientific consulting on the development of the larger 'competence network' for optical technologies in Berlin and Brandenburg (cf. Sydow, Windeler, & Lerch, 2007), see also: http://www.optecbb.de/lang/en/home.php, last access 2014-08-29.

8. Conclusion

In this work, I focused on a world-wide technological innovation process in public lighting. But instead of choosing an innovation-oriented macro- perspective, as most current studies and reports on LED technology do, I analysed *early public LED installations* from an urban point of view. This shift in perspective gains relevance as cities are drawn into the global innovation activities around SSL technology. In the face of market failure, they are encouraged by current EU demand-side innovation policies to procure LED technology and create a lead market for SSL technology in Europe (cf. European Commission, 2013-06).

This study presents a close-up analysis of how LED technology was introduced in Lyon and Berlin. It showed that these two cities *vary* considerably with regard to how they appropriated LED technology and embraced the chance and challenge of using it innovatively. Furthermore, the six LED projects I analysed in this work showed that the success or failure of pilot projects or innovation 'showcases' not only depends on the right moment, the right technology but also on the right team of innovators and technology users and on the right place and the right observers.

In this concluding chapter, I will first summarise the key arguments and findings of this work and outline their analytical implications (8.1). Subsequently, I will reflect on the theoretical relevance of my research for sociological innovation research (8.2). Naturally, this qualitative study on an ongoing innovation process also has its limits (8.3). Blind spots, open question and points for further research will be outlined in the last section.

8.1 Empirical findings and analytical relevance

The 'revolution in lighting' is still ongoing and LED light for cities still in the making. My aim was therefore to illuminate *how LED lighting was introduced* Lyon and Berlin, as two opposite examples and extremes in Europe. This choice of two most-dissimilar urban field sites and my explorative approach allowed me to discover a number of consequential differences and case-specific particularities. In this concluding chapter, I will only highlight what I consider the most interesting findings.

8.1.1 How LED lighting was introduced: Test-show trajectories

In 2011, when Lyon and Berlin built their first LED-lit streets, the technology had already been used in public lighting but it was still new enough to be fraught with uncertainties, as outlined in chapter 4. While everybody agreed that LED lighting was a promising and highly energy-efficient light source, some earlier installations had revealed quality problems like flickering lights, glare or degrading LEDs. In addition to that, the supposedly long life span of LED products had not yet been proven in real-life and in real time, and the technology was and still is developing so rapidly that standardisation was lagging behind. Potential LED users were divided between scepticism and enthusiasm for the new technology. So were the light planners in Berlin in Lyon. Curious as they were, they were held back by the risks of investing in an expensive technology that would cause them maintenance problems or be outdated in no time. As a result, they first introduced LED technology on a small scale and in a particular way, namely as test cases or 'showcases'. *The question of how LED lighting was introduced in cities can thus be answered rather generally: it was introduced by testing and showing it in real-life situations.* These observations are in line with my theoretical assumptions, namely that technology needs to be tested in order to work and that innovation needs to be shown to observers in order to be valorised.

Looking closer though, I also observed that the projects did not always turn out as projected. The LED demonstration in Leibnizstraße did not show what it was supposed to show. Montée du Boulevard was designed as a test but later shown to professional visitor groups and publicised in print. These observations have had analytical consequences for this thesis.

First, they made it difficult to pin down what I was looking at. The challenge was thus to conceptualise local LED projects as part of a global innovation process *without* specifying whether they reduced or produced uncertainty, for instance, by either showing that things worked and the light quality was good, or by causing compatibility problems and raising new issues. My solution was to conceptualise the projects very generally as *early public installations*, which then allowed me to draw out their *test-show trajectories* (see Figure 7-1).

Second, these trajectories are theoretically relevant as they challenge macro-analytic essentialist policy-oriented research on pilot projects (2.2.1, W. Baer et al., 1976; Myers, 1978) as well as demand-side innovation policies (see appendix 10.2), both of which suggest that installations of mature technology *are* demonstration projects. At the same time, it underlines the findings of micro-analytical studies on ‘public experiments’ in the widest sense and scientific knowledge production, which highlight the precarious status of demonstrations, especially if they take place in front of heterogeneous audiences (Shapin, 1988). This literature addresses problems of testing and showing from an epistemological perspective and suggests that *showing innovation* with the aim of producing evidence and reducing uncertainty requires either a *select and preferably homogenous audience* or well-staged and *well-rehearsed ‘displays of virtuosity’* (2.2.3, Collins, 1988). Table 2-2 outlined the two different perspectives as follows:

Analytical issue	Macro-analytic perspectives	Micro-analytic perspectives
Testing or showing?	Depends on technological maturity and project timing	Depends on spatial settings and the heterogeneity of audiences

Table Excerpt from Table 2-2

For analysing test-show trajectories, the second micro-analytical approach proved definitely more salient. I found that spatial settings mattered in the sense that the Lyon test sites, Rue Thénard and Rue de l’Oiseau Blanc, were indeed established in remote public spaces and observed by a homogeneous group of lighting engineers. In contrast, the LED gaslight imitations in Falckensteinstraße were staged in a busy spot and in front of heterogeneous observers, including lighting engineers, monument preservationists, urban designers, politicians, critical gaslight amateurs and the local media. The presentation in Falckensteinstraße was thus the most heterogeneous among the six projects as illustrated in Table 6-1 and 7-1.

As the case studies show, the heterogeneity of observers resulted from the fact that lighting engineers, manufacturers, light managing firms, urban designers, politicians, gaslight enthusiasts and citizens literally *saw* the new lights differently and hence engaged differently, mobilised different evaluative criteria and imaginaries and produced different forms of evidence.[395]

These differences also raised further questions. Why did the heterogeneity of the projects and their ‘visibility’ vary, despite the fact that they all took place in openly accessible public

[395] Theoretically, these findings correspond with the perspective of the Economie of Conventions and Thévenot’s notion of plural cognitive ‘modes of engagements’, ‘investments in form’ and different ‘worlds of worth’ (Boltanski & Thévenot, 2006; Thévenot, 2007). However, this point remained underspecified in this work.

spaces? In my analysis I argued that heterogeneity was managed in the planning process. In doing so, I distinguished between two specifically urban project management practices. First, the planners pursued *socio-spatial placing strategies* in order to create 'privacy' or 'publicness' in urban spaces, for instance, to avoid the attention of *heterogeneous audiences* when they tested and to produce the greatest possible appeal when they wanted to show LED technology in use. Second, since the locations of LED projects could not always be deliberately chosen to match the project objectives, planners also engaged in a complementary, more general planning practice which can be described as *socio-material network formation.* In line with actor-network theory, this mutual testing of relationships ensured that new and old *heterogeneous actors and things* would adapt to each other and that the relationship would hold together. I will briefly give examples for both practices, which I consider specifically *urban innovation activities*.

The socio-spatial 'project management' was particularly obvious in the cases of the two Lyon test streets, Place Bellecour, Altonaer Straße and Leibnizstraße. In my analysis I described how the project planners carefully chose the right urban settings in which to install the new luminaires in public and thus *managed the 'publicness' and 'privacy'* of their test and demonstration activities (7.1.2). They thereby considered both the geographical connectedness of urban spaces and their symbolic function. For instance, the Lyon test streets were rather remote, only visited by residents and had no particular symbolic appeal. The municipal lighting department (DEP) used them as test sites. At the same time, the DEP planners were initially opposed to installing LEDs on Place Bellecour, since they considered the technology too uncertain for Lyon's central traffic hub and highly symbolic square. Similarly, the municipal public lighting team of the Berlin Senate Administration (SenStadtUm) chose Leibnizstraße for their projected LED demonstration as they considered the 'City West' more prestigious than 'some Eastern District'. The team of lighting manufacturer and designers, who planned the LED product presentation in Altonaer Straße, first rejected a street that SenStadtUm had offered them and finally chose a symbolic location where they could stage their new product line in front of the Berlin Victory Column.

Socio-material 'project management' was crucial in all six cases and underlines my micro-analytical assumption that to 'adopt is to adapt' (Akrich et al., 2002a). From the ANT perspective, this adaptation can be described in relational terms as a process of network formation. New technologies are adapted as they are linked to existing artefacts and infrastructures and enacted in familiar settings and routines. But it is not only the innovation that is adapted but also all the other ‘human and non-human actors’ involved in this process of socio-material network formation (7.1.1). Accordingly, I could observe that urban technology users saw a need to develop new skills in order to operate LED lighting. The Lyon DEP adapted their maintenance intervals. The Berlin light manager was relieved to adapt the contracts of his subcontractor in charge of the repair of gaslights. But LED technology was also adapted to site-specific requirements, which was most obvious in the cases with customised solutions like Place Bellecour, Montée du Boulevard, Saalestraße and Falckensteinstraße. Whereas in the first two cases, the light distribution of the new LED luminaires was adapted in the most efficient way to illuminate the largest public square of Lyon or an eerie stairway, the LED gaslight retrofits were not customised to meet specific *spatial* requirements but to imitate the light distribution and light colour of the gas lanterns.

Other adaptations became necessary in the planning process in response to socio-material incompatibilities. On Place Bellecour, overvoltage protection devices were installed to ensure that the old electricity grid would not harm the new electronic light source. In Montée du Boulevard, the initial cable could not adapt to the cold temperatures and broke. The manufacturer learned from this experience and found a new cable for the product line in question. In Leibnizstraße, the Berlin energy supplier and light manager were unwilling to adapt to the new telemanagement system so that SenStadtUm was not able to exploit the energy saving potential of the new LED installation.

We can conclude that getting the timing right and using mature technological innovations are necessary but not sufficient conditions for the ‘application’ and ‘information success’ of early public installations. A further element is necessary in the form of competent urban technology users that can prevent that a technology demonstration from turning into a public trial. As my analysis showed, the municipal socio-spatial management and adaptation of early public installations to specific situations was crucial for the recognition and valorisation of the innovation. It seems that the particular municipal contribution and competence lies in knowing not only their allies but also their audiences and sites of innovation.

8.1.2 Innovating: Socio-material networks shape test-show trajectories

As outlined in 7.1.1, this adaptation work was a prerequisite for the successful completion of installation projects and thus decisively affected their test-show trajectories. However, the comparison of these six trajectories also revealed some puzzling differences. First, I found that although both municipalities introduced LED technology around the same time, namely when the technology was mature enough for public lighting but still fraught with uncertainty, the Lyon public lighting service DEP tended to *test* LED lighting while the Berlin municipal engineers at SenStadtUm tended to *show* their innovation projects in public. Second, despite these objectives, the Lyon LED projects were later more widely recognised than the LED demonstration projects in Berlin. In my analysis I showed that *the existing public lighting networks* can explain these *city-specific test-show trajectories*.

The analytical implication is that, in contrast to what is suggested in the ANT innovation model, it is not only the 'spokespeople' of innovation and their 'art of interessement' that matters, but also the *quality* of already established relationships on site. In other words, institutional and cultural settings shape the way in which new technologies are introduced (Rammert, 1990). Analysing the urban public lighting networks of Lyon and Berlin, I found that innovating in this domain is easier in the French City of Light than in the German capital.

As I showed in chapter 5, the Lyon public lighting network is well-established in terms of public-private collaborations and finances. I described it as coherent and expanding. Most importantly, the City of Light has a reputation as a pioneer in urban lighting, and the civil engineers want to stay ahead of new developments in their professional field. This concerns technological innovation as well as new sustainable approaches in urban light planning. This goal is reflected in the DEP's organisational culture ('we test') and also inscribed in the official Lyon lighting policy, which highlights the need for experimentation. The DEP participates in scientific real-life experiments (EVALUM), explores the aesthetic value of urban lighting in the course of the Fête des Lumières and tests its competences outside Lyon by managing lighting projects in other countries.

Accordingly, the Lyon LED projects were carried out in an explorative but also prudent way. The DEP do not have to show the world that they can innovate but they do have a reputation at stake. In line with their well-established methods and lighting practice, they introduced LED lighting cautiously by testing it in different respects. The three projects reveal at least three modes of testing: The performance of the new technology was tested in all three projects, especially its advantages in terms of homogeneous light distributions and energy-efficiency. The operability was and is still being tested in Montée du Boulevard, where maintenance played an important role, and in the test streets, where new maintenance intervals are tested. Third, the social acceptance of the new light was indirectly being tested, especially on Place Bellecour, where the light levels are reduced after midnight. Since citizens did not complain, the LED projects passed that test. I conclude that the 'prudent' DEP planners introduced LED technology not only because it was new and better. Their initial reluctance to install LEDs on Place Bellecour shows that the decision makers were cautious and sceptical. Yet at the same time, their expert image and their self-image required them to *test* the new technology in order to stay up-to-date. Introducing LED technology was naturally part of their more general experimental approach and organisational culture of testing and life-long learning. Thus, this incentive to *engage in exploration* is closely related to the DEP's international *public* reputation as a *pôle de competence*, a centre of excellence, in urban lighting.

In Berlin, the situation is very different and the politicised situation leaves the public lighting team at SenStadtUm little room for experimentation. Since reunification, the public lighting network has been far from established and is constantly on trial: The public-private contract does not ensure 'care-free' working relationships but calls for renegotiation. Furthermore, the Senate Administration, including its small public lighting team, has been downsized and is obliged to reduce public spending even further. At the same time the Berlin lighting infrastructures are outdated and in need of modernisation.

In contrast to the long-established Lyon light planning policy, the Berlin light plan was only presented in 2011 and caused controversy. The comprehensive strategy is intended to act as a guideline for integrated light planning and contains an implementation regulation meant to coordinate the collaboration between the Berlin state and districts as well as the private light managing firm. Yet lighting engineers have objections to the new regulation and criticise its underlying urban planning approach from a laboratory science perspective. Finally, the Berliners are not silent observers. The gaslight amateurs have opened the 'black box' of public lighting and question their lighting experts in public.

In this situation, the SenStadtUm team seems to have little space for exploration. Civil engineers report having the impression that mistakes are not allowed. Instead, they are trying to re-establish working relationships with their private contractors and to settle the public conflict on the refurbishment of the Berlin gaslights. Against this backdrop I have interpreted the early public LED installations in Falckensteinstraße and Leibnizstraße as attempts to *show* all the heterogeneous local observers that the situation is improving. However, as we have seen, only the gaslight refurbishment was ultimately successful from the municipal perspective. It seems that the *politically problematic situation* and the public visibility of the Berlin public lighting practice made *public engagements and justifications* appear more opportune than public testing.

This brings me to the second puzzle, which concerns the test-show trajectories of the projects. My analysis suggested that although the Lyon municipal engineers cared little to *show* their LED projects in public, their early public installations were widely recognised by lighting professionals, whereas the Berlin projects have left little traces. In this respect, my argument is twofold. On the one hand, the dissemination of project-related information seems directly related to *city-specific publics* for urban lighting—I will come back to this point. On the other hand, the Lyon projects seemed to be planned more consistently than the Berlin projects, which was most obvious in the contrast between Leibnizstraße and Place Bellecour.

In both cases, dimmable LED technology was installed in October 2011. Yet while the Berlin municipality was a driving force in the planning process and was enthusiastic about being an LED adopter, the DEP planners were at first sceptical. After the installation however, the situation was reversed. The Berliners were disappointed after an unfortunate inauguration event. The Lyonnais were positively surprised by their customised LED solution and the 'world of lighting' took notice and discussed the project. By analysing the installation projects as processes of network formation (Akrich et al., 2002a), I found that in Berlin, not all the relevant entities had been enrolled. In particular, the interests of the SenStadtUm team, the Senate, the private light manager, the LED manufacturer and the energy supplier had not been fully aligned. The manufacturer lost interest, the energy supplier and light manager were not part of the planning process and did later not cooperate and the Senate had always been sceptical. As a result, the project neither showed that Berlin had successfully implemented LED lighting nor did it produce the expected effect in terms of energy and cost saving.

This is not to say that Berlin is not capable of managing projects well. The LED-gaslight-imitation case shows the opposite. However, world-changing 'ontological' work seems far more difficult for the Berlin SenStadtUm, where neither resources, nor the terms and conditions of the public-private partnership, nor the social acceptance of the public lights can be taken-for-granted. In Lyon, in contrast, the spokespeople of LED technology, who were in two of three cases lighting designers, successfully translated their project for the manufacturer, the DEP, the urban and landscape designer, the French monument protectionists and even the local press and thus mobilised an even more heterogeneous network of actors. In addition to that, the success of the project was ensured by a number of material 'interessement devices', including a 10-year warranty for the LED luminaires and a series of overvoltage protection devices. In line with ANT, we can conclude that the 'interessement' and *sustained* enrolment of all relevant entities is a prerequisite for 'application success' (cf. W. S. Baer et al., 1976). Beyond ANT, we can argue that the successful mobilisation and adaptation in Lyon was no coincidence. Instead, the collaboration between the actors from the urban public lighting network, including lighting designers, has been well established since the first Lyon light plan in 1989 (Marescaux, 2002). Good working relationships of this kind have yet to be re-established in the reunified German capital.

However the existing institutional and cultural settings in Berlin and Lyon also had a material effect on the introduction of LED lighting. Looking at the light plans, we see that both lighting policies clearly define which kind of luminaires and light colours are eligible for their cities. Both light plans rule out cool-white LED lighting, but they also rule out yellow high-pressure sodium lamps (HPS), which can still compete with LED lighting in terms of energy efficiency. I also showed that the light plans implicitly set the rules for how to deal with innovation. While the experimental approach of the Lyon DEP ('we test') is also highlighted in the *Plan Lumière*, the Berlin *Lichtkonzept* promotes the preservation of urban life worlds, which includes both the daytime look of typical luminaires and the night-time feel of illuminated streets.

As a result, LED lighting was introduced differently, in city-specific versions. In line with Lucy Suchman (2012) I described them as *city-specific LED configurations*.[396] The Lyon *cutting-edge LED configuration* can be understood as part of the DEP's larger experimental strategy. In contrast, the Berlin Senate Administration commissioned researchers and developers to imitate gaslight with LED technology in order to preserve the look and feel of

[396] In contrast to the ANT notion of configurations (2.2.2), Suchman explicitly highlights the non-material imaginary dimension of the analytical device. Suchman's 'trope' comes very close to the 'analytical construct' of the 'cultural configuration' that my research unit describe in our research programme (Hutter et al., 2010) but it has the advantage of highlighting the tension between context and figure, in my case cities and 'LED'.

Berlin's streets. Berlin's *reassuring LED configuration* is thus in line with the urban design approach as it is outlined in the light plan. However, we have also seen that the light plans are a symptom rather than an explanation for the *city-specific LED configurations*. To fully understand Berlin's preserving and Lyon's experimental approaches, we have to follow the attention and focus on the city-specific audiences for public lighting. Again the 'city-specific publics' of Berlin and Lyon are closely related to their existing urban public lighting networks.

8.1.3 In public: City-specific observers shape LED configurations

As stated in the introduction to this work, I set out to show *that urban observers of early public LED installations shape the technological innovation.* I also argued that specifying the identities of these observers would be an empirical question. It was indeed, and I find the result quite astonishing. To make a long story short, I found that the *Lyon public* is an international expert audience with an interest in global urban lighting issues, while the *Berlin public* is local and heterogeneous. It includes laypersons, gaslight amateurs, urban designers, monument preservationists as well as public and private light planners with a background in light engineering. Against this backdrop, I argue that *the Lyon cutting-edge LED configuration and the reassuring Berlin LED configuration are not primarily shaped by concrete site-specific needs but by particular modes of observation and valorisation* as they are typical for the cities' specific light-related 'publics'.

These different modes of observation and valorisation can be best understood if we reconsider what makes early public installations 'public'. In chapter 2, I have outlined *three situations* which heighten the public visibility of otherwise taken-for-granted, black-boxed public lights and lighting infrastructures.

First, lighting technology attracts attention if it becomes *noticeable and observable*, either because of qualitative changes in light levels in the course of technological transitions or because the technology does not work as it should. This is clearly the case in Berlin, where gaslights frequently burn during the day and do not work at night. In contrast, Lyon has much fewer failure reports and its lighting equipment seems in good shape. Although I cannot prove the relationship, this difference might be a reason why citizens in Lyon seem to 'not care'. In

Berlin, in contrast, the black box seemed already wide open when LED lighting was introduced—and hence it was shown rather than tested, as described above (7.1).

Regarding the visibility of the technological transition, I observed that both public lighting services successfully anticipated what was socially acceptable in terms of light levels and light colour. Thus, the LED conversions did not open the technological black boxes any further. The LEDs in Falckensteinstraße seem to have even contributed to closing them again (6.2.2). The observability of lighting technology seems a condition for lay engagement.

Second, noticeable changes, broken lights or culturalised gaslights can turn into 'matters of concern' (Latour, 2004, 2005) and mobilise actors to actively participate in 'issue networks' (Marres, 2007). This connection is most obvious in Berlin, where gaslights have become a public issue and gaslight amateurs thereby even redefined the material facts: 'outdated' infrastructures were transformed into 'historic' cultural heritage. Their concerns clash with technology users' interest in operable, efficient and maintainable public lights. Accordingly, the second situation, in which public lights become public, can be characterised in terms of conflict or controversy. Such conflicts may not only hinder but also promote new lighting solutions.

As my case studies show, the issues raised mostly concerned the compatibility of public lighting and urban design or monument preservation. These 'matters of concern' introduced new evaluative criteria for the valorisation of LED lighting. In addition to the general efficiency-related arguments, the installations were also evaluated with regard to their place-specific atmosphere and symbolic value, as was most evident in the cases of Falckensteinstraße, Montée du Boulevard and Place Bellecour: In Falckensteinstraße the objective was to replace gaslights with LEDs without changing the luminaire design or the look and feel of the street even if that meant that the LEDs were not as efficiently deployed as they could have been. On Place Bellecour, the the monument preservationist's veto paved the way for a customised LED solution that later positively surprised the sceptical municipal engineers and was well-received by the international lighting scene. The LED fixtures in Montée du Boulevard solved not only maintenance problems in the sloping terrain; they also seemed perfectly suited for regenerating the dodgy staircase with the great panoramic view of Lyon in its medieval surroundings.

While both cities' light plans offer an institutional framework governing how to mediate between technical traffic and safety requirements and urban design issues, this mediation seems more established in Lyon than in Berlin, where the collaboration between the urban design and public lighting teams was only institutionalised in the course of the development of the 2011 light plan. The gaslight conflict is an additional factor that mobilised a Berlin-specific heterodgeneous audience. Against this backdrop, I conclude that concrete urban design and preservation issues mobilise local observers to take an interest in public lighting, inculding early public LED installations. This rather preservationist, design-oriented public seemed more important in Berlin than in Lyon, where the urban design department and DEP have been collaborating for the last 25 years and citizens apparently 'don't care'.

This third situation occurs when public lighting issues are mobilised as part of larger political agendas as in the case of the Lyon 'nocturnal urbanism' (4.3.3) or in the context of EU and national climate change mitigation policies. These publics are closely linked and assemble around global discourses, as the example of the Lyon-based city network *Lighting Urban Community International* (LUCI) shows. As outlined in chapter 7, the DEP actively participates in LUCI debates and programmes on sustainable lighting and exchanges ideas and information with colleagues, lighting designers, urban planners and industrial innovators in France and around the world. Berlin on the other hand, seems little involved in the ongoing grand transdisciplinary debates on the future of urban lighting. In contrast to Lyon, Berlin is also not a meeting place for the international urban lighting scene. In this respect, the Fête des Lumières plays a crucial role as the moment when Lyon's international expert public materialises and assembles in the City of Light. As such, and like most LUCI events, it thus also has the effect of grounding global debates on innovative, sustainable, place-making or image-building urban lighting practice by giving expert visitors from other cities the chance to see their colleagues' work and solutions with their own eyes and on site.

Against this background, I conclude that the Lyon *cutting-edge LED configuration* and the *Berlin reassuring LED configuration* are not only pushed by the global technological developments and EU or national demand-side innovation policies but also pulled, that is, expected, recognised and evaluated by city specific publics for urban lighting. In other words, the *cutting-edge Lyon LED configuration can be considered the result of 'private' testing within a well-established coherent lighting network and 'public' showing in front of an international audience of urban lighting experts*, whose discourses help shape boundaries of the ‘figure’ technology and mobilise imaginaries of intelligently controlled LED solutions for public lighting (Suchman, 2012). Meanwhile, the *reassuring Berlin LED configuration seems the result of an exceptional effort of private testing, namely in the course of an extraordinary municipal innovation programme, and was shown to local expert, amateur and especially lay audiences, represented by the local media.* These mobilised quite different imaginaries, namely the notion of efficiently lit but still familiar urban spaces, unchanged by innovation.

8.2 Theoretical relevance

The focus of this work was not on theory building but on conceptualising an ongoing technology implementation process from the user perspective. Nevertheless my empirical findings also prompted some theoretical reflections on innovating in cities and innovation in general.

On the one hand, my findings support existing research about user-producer relationships. The ‘exigent’ municipal light planners in Lyon helped improve LED products, for instance in the case of Montée du Boulevard. By participating in the EVALUM real-life experiments and the activities of the Cluster Lumière they also play an active role in the regional system of innovation. In this sense, the Lyon light planners can be described as competent ‘lead users’ and ‘professional users’ (B.-Å. Lundvall, 1985; E. A. von Hippel, 1986). Meanwhile, the downsized Berlin public lighting team seems not to be in the position to play such a role.

On the other hand, I found that early public installations of innovation *offer city-specific sites for valorising new technologies*. As we have seen, LED technology was augmented through the mobilisation of site-specific values like urban design issues, monument preservation, urban images and cultures. Accordingly, the evidence produced in installation sites celebrated not LED products but LED lighting *in place*. In this sense, the installation of LED lighting transformed an abstract global innovation into concrete configurations that worked in a particular urban situation. Furthermore, I showed that city-specific heterogeneous audiences played an important role in this and that these urban observers of innovation did not assemble themselves spontaneously or coincidentally but were already assembled as a result of city-specific urban lighting practice and policies.

As I will briefly outline, these findings challenge demand-side innovation policy and multi-level perspectives on technological transition and underline the need for critical sociological perspectives on innovation.

8.2.1 Can cities shape innovation…?

In this work I frequently mention current EU demand-side innovation policies and incentives for innovative public procurement that aim to create lead markets for new technologies like solid-state lighting. These policies reflect a more general shift in innovation policies (OECD, 2011), which has been accompanied by policy-oriented research on the subject (Edler & Georghiou, 2007; Edquist & Hommen, 1999). However, although this literature assigns municipal public procurers an important role in the innovation process it seems to pay little attention to the particularities of urban situations. Furthermore, the pro-innovation bias of this research supports a macro-analytical *economic* perspective that cannot account for the urban innovating and local value attribution. While the positive regional and national economic effects of public procurement are highlighted, diverging local, cultural or political rationales seem secondary, if not problematic, and they are viewed as an impediment to early adoption and the creation of lead markets (cf. Dalpé, 1994; Edler & Georghiou, 2007; Edquist & Zabala-Iturriagagoitia, 2012, see appendix 10). What seems to be missing in the discussion is a perspective that can account for the complexity and messiness of urban situations, for the plurality of local needs and legitimate interests and their productive potential.

This potential seems even more relevant as radically new technological solutions and the demand for these solutions co-evolve (cf. Geels, 2002). As the example of LED lighting shows, urban actors can actively contribute to the development of such new demands—not only as passive public procurers or competent ‘professional users’ but also by developing new approaches and public lighting strategies which valorise LED lighting.[397]

Against this backdrop, I agree with Mike Hodson and Simon Marvin who argue that the idea of cities as a test bed for new technologies and socio-technical systems brings with it the risk of ‘dropping in’ technologies and overlooking ‘the possibilities of local agency’ (2009, p. 530). Taking multi-level perspectives on technological transition as a theoretical point of departure (cf. Geels, 2002), they argue that ‘a key scale’, namely the urban scale, ‘is currently

[397] As pointed out above, HPS luminaires are equally efficient but they cannot be dimmed as easily as LED lighting and they give yellow light, which was incompatible with the lighting strategies of Berlin and Lyon.

inadequately conceptualised or perhaps at worst missing' in multi-level perspectives on technological transition (2009, p. 516). In their research they frame the research gap as both an empirical and methodological question: 'Can cities shape socio-technical transitions and how would we know if they were?' (Hodson & Marvin, 2010).

While Hodson and Marvin stress the role of intermediary organisations and their capacity to bundle and align global and local visions of technological change (Hodson & Marvin, 2009), my situated perspective highlights the socio-material and socio-spatial contribution of urban actors in innovation processes. As my analysis showed, in the cases I analysed, the urban actors' capacity to mobilise their urban public lighting networks contributed in crucial ways to the successful implementation of the new technology. Similarly, their implicit or explicit awareness of the 'publicness' of the situations in which they tested and presented technological change affected the ways in which the innovation was presented and valorised in public. The fact that the actors in Lyon and Berlin differed with regard to how they performed these urban innovation activities of testing and showing underlines the need for empirical studies and theoretical concepts that can account for both the urban and the innovation perspective on niches, pilot projects, technology trials and demonstrations (cf. Geels & Schot, 2007; Harborne & Hendry, 2009; Hendry et al., 2010; Kemp et al., 1998).

8.2.2 Relocating innovation in front of heterogeneous observers

In my introduction I suggested that there is more innovation going on in public lighting than LED development. Focusing on the technology I found that its value in public lighting was not only the result of its efficiency, light quality and long life span. Instead, the technological innovation was aligned with local lighting practices, linked to environmental discourses about climate change and 'light pollution', evaluated in relation to nocturnal urbanism and urban development and mobilised in the context of architectural preservation and cultural heritage debates. From the urban perspective, introducing LED lighting was not a 'no-brainer', as the Vice President of the European Commission suggested (European Commission, 2011-12-15a); it required local adaptation and valorisation.

In this situation, sociological perspectives on innovation allowed me to conceptualise this *ongoing* innovation outside of R&D laboratories and markets as *innovating in public.* More precisely, I conceptualised innovation as a performative act of testing and showing in front of heterogeneous publics. The combination of 'ontological' and 'epistemological' pragmatic perspectives (2.2.2 and 2.2.3), especially from studies on science, technology and society (STS), allowed me to analyse how innovators or 'spokespeople' actively shaped social and *socio-material and socio-spatial relationships*, in order to render their public innovation activities visible or invisible.

This performative sociological perspective has two analytical implication that are of theoretical relevance. On the one hand it draws attention to the *material settings* in which innovation is placed and staged. On the other hand it highlights the central role of the *observers* of innovation. Instead of assuming that material settings and observers are just out there and are either essentially problematic or open to accomodating or welcoming innovation, the performative perspective turns *the question of material settings and observers* into an empirical analytical problem.[398] Thus, it corresponds with valorisation-oriented sociological definitions of innovations. As previously outlined, if we define innovation as something that is recognised as new and better *by observers* (Braun-Thürmann, 2005) we need to specify the places of these observations and also who the observers are.

The advantage of this open and non-essentialist approach is twofold. First it allows researchers to explore the heterogeneous ways in which observers with different cultural, professional or personal backgrounds engage with and evaluate newness in their familiar worlds (Thévenot, 2007). As we have seen, the evaluation of LED lighting in terms of efficiency was just one viewpoint among many others. The relevance of the sensory experience and valorisation of the new light suggests that innovation in lighting has something in common with the valorisation of experience goods or design objects (Hutter, 2011; Parolin & Mattozzi, 2013). As we have seen, lighting engineers, urban and lighting designers as well as gaslight amateurs draw and rely on their trained and/or professional visions, categories and tastes when observing innovation in lighting (Goodwin, 1994; Hennion, 2004; Knorr-Cetina, 2007). In light of the increasing relevance of creative industries, this sensory dimension of innovation and innovating seems an interesting research area for sociologists with an interest in valorisation and value attribution (cf. Berthoin Antal et al., 2015)

[398] The salience of this analytic attention for socio-material settings and audiences is also evident in social-scientific research on markets or market places (cf. Callon, 1998; Moeran & Pedersen, 2011; Potts, 2011).

The second advantage of the valorisation perspective lies in the possibility to 'relocate innovation' (Suchman et al., 2008). As we have seen, the reassuring Berlin LED gaslight imitations might not be as relevant for LED innovators as the cutting-edge Lyon technology tests. However, if we look at it in terms of value attribution, this local reinterpretation and creative adaptation of a still malleable emerging technology can also be considered a full-fledged innovation—something new and better from a local point of view. As Lucy Suchman pointed out, creating innovation in one place and making it spread all over the world is a kind of hegemonic gesture (Suchman, 2008). The valorisation perspective highlights the potentially powerful role of users and non-users as observers of innovation and the empowering act of attributing value to 'the new'—or refusing it.

With this in mind, we can crically reconsider my observations especially with regard to the silent observers, the citizens and residence of innovatively lit streets. Doing so, we see that the innovators' 'art of interessement', that is their success in mobilising all relevant people and things, was only one aspect of their public innovating. The other complementary part of their success can be described as an 'art of letting sleeping dogs lie'. By installing LED technology in the right places, by choosing the right warm-white light colours and dimming the light levels at the right time, the innovators were, in most cases, successful in rendering their innovation activities invisible for lay audiences or keeping socio-technical black boxes closed. I conclude that 'the art of letting sleeping dogs lie', in other words, the art of *avoiding undesirable* public attention in the form of citizens' complaints, bad press or political concerns, is at least as important for success in innovation as attracting interest and attention. Obviously, the critical point here lies in the assymmetry of innovator-observer relationships. But luckily my research was not on public nuclear tests and experiments, but on the far more boring topic of testing and showing in public lighting, which brings me to my last point, the limitations of this study.

8.3 Limitations and open questions

The aim of this research was to explore an ongoing global technological innovation process from the user perspective. Hence, the first limitation was intrinsic to my research subject. LED technology for public lighting is still being further developed; new test and show cases are constantly being installed; the European Commission has continued to encourage demand-side innovation and to grant SSL projects. I had to start writing and to finish my doctoral thesis although the Lyon lighting engineers had begun to test and show presence-controlled LED solutions. Finding out more about the practical consequences and public responses to these early public installations of ‘intelligent’ lighting would have been highly interesting as the radical newness of the new electronic light source does not lie in the mere replacement of old street lights but in the installation and programming of adaptive lighting systems as outlined in chapter 4.

Methodologically, my grounded approach and situational analysis allowed me to collect a lot of fascinating messy data. However, some relationships remained unexplored, for instance the relationships between the local lighting clusters in the urban public lighting networks. This data offers the material for a future analysis of the regional innovation systems. In terms of case selection, the dissimilar cases of Berlin and Lyon revealed how different the socio-material public lighting networks of cities and their respective publics can be. However in light of regional differences regarding the social acceptance of light levels and national differences between France and Germany, it would have been interesting to also compare Lyon and Berlin to other French and German cities, especially with regard to the impact of national climate-change policies or energy-supply networks, which was only briefly mentioned in chapter 5.

What seems even more important is an analytical limitation regarding the generalisability of my observations on public innovation activities. As mentioned above, the public appeal of light-technological innovation is hardly comparable to that of nuclear technologies or consumer electronics also involving semiconductor technology. *Innovating in public* in the domain of lighting might follow different ‘laws of attraction’ due to the specificity of lighting technology and its uses. On the one hand, artificial light has a positive symbolic and cultural connotation—which goes beyond the initially mentioned semantic relationship between the equally positively connoted notion of innovation and the light bulb. On the other hand, the question of ‘who are the users of light technological innovations?’ is not that trivial. As we have seen, public lighting services tend to be invisible to laypersons and citizens are often silent observers of light-technological innovation. At the same time, the lighting producers sell technology users their products by referring to the end users’ needs, that is, the diverse needs of users of public spaces in their various roles as car drivers, pedestrians, residents or citizens. Photometric laboratory experiments make these ‘needs’ known and they are translated into the right light levels, colours and colour temperatures. In addition to that, and as this study has also shown, municipal and private urban technology users are also actively involved in ‘configuring the user’ in in the course of their ‘usability trials’ (Woolgar, 1991).

Against this backdrop, I suggest that my assumptions about the performative innovation-shaping role of heterogeneous observers should be tested in other research fields than lighting or urban infrastructures. We might find that the observers’ valorisations and users’ engagements are far more homogeneous if we look at personal computers—although there is evidence to the contrary (cf. Lindsay, 2003). Another question is what group or groups might be the equivalent to ‘city-specific publics’ in other domains and research fields. Looking at the nuclear industry, it definitely seems that country-specific publics can at least shape the phasing-out of that technology on the national scale. I can also imagine scene-specific publics within the same city for all sorts of innovation tests and ‘showcases’.

To conclude I would like to point out that there are not only limitations but also almost unlimited research opportunities in the ‘epistemical wasteland’ of urban lighting (Hasse, 2007a). Given the high level of innovation activities in the field of urban public lighting, which go well beyond the LED revolution, I was only able to provide a mere snap shot here. I am therefore looking forward to more studies and research in this inspiring transdisciplinary research field and can look back on an interesting research journey which taught me to see the public light.

Appendix

9. Histories of lights and cities

In the 21st century, public lighting is taken for granted. It shapes the nocturnal image of contemporary cities and their public spaces. Despite the fact that the larger part of contemporary social interactions takes place in urban spaces during the dark hours of the day, there is as yet only little social research that focuses on the nocturnal city as a particular social time-space. 'The geography of night is just now receiving rightful attention', writes John A. Jakle in 2001 in his book *City Lights*. The human geographer Jürgen Hasse describes urban lighting as an 'epistemic wasteland' arguing that the practical embodied professional knowledge of light planners is not matched by reflexive systematic knowledge about the effects of artificial lighting in urban night planning (2007a).

In this situation, historians' studies on city lights, lighting practices and social night-life in the past, offer a valuable point of departure for my research. Their histories of lights and cities are closely linked to technological change. This is due to the paradoxical fact that artificial lights are mostly taken-for-granted and invisible as long as they are not changed. Historians have often looked at technological innovations as phases in which so-called black-boxes, taken-for-granted relationships between actors and things, were opened and reconsidered, when 'matters of fact' were turned into renegotiable 'matters of concern' (Latour, 2009). As historian Ute Hasenöhrl points out, controversies over light-related issues broke 'in times of transition when new technologies and infrastructures were tested and implemented' (Hasenöhrl, 2015). The testing and implementation of LED light constitutes the latest chapter of such histories.

In this chapter I focus on times of technological transitions and their social histories in order to trace continuities and discontinuities in the urban configuration of public lighting today. There is not just one history of urban public lighting but histories. They add a long-term perspective to my research as they reveal that current debates on light quality and the public-private organisation of public lighting have traditions. Historic accounts also reveal how lighting practices and urban night-life co-evolved, starting in European cities. They also suggest that social trends instigated technical development as much as the latter facilitated the transformation of urban spaces after dark. Innovations were always also political issues. Technological changes were facilitated by powerful spokespeople and sometimes opposed by affected parties or citizens. Thus, the following histories can illuminate the culturally contingent evaluative frames against which LED technology is perceived as new and better.

Histories of urban lighting can draw attention to the cultural, historical and city-specific relations between lights and cities. Light is constitutive for public night life, building the basis for orientation in urban space and eye contact between human beings. Georg Simmel takes the exchange of mutual glances as a prerequisite for human interaction and sociability and points to the particularly urban formats of such visual engagements. He argues that city life privileges the visual sense and explicitly points to the technologies that lead to this 'immeasurable prevalence' (1908). Before the emergence of public mass transport systems, people were never in the position to gaze at each other for minutes or hours without also talking to each other.[399]

The evolution of lighting technology thus responds to a general human preference and demand for lit environments as well as specific socio-cultural and especially urban configurations. Artificial lights for cities first alleviated the human fear of the dark. But apart from safety and control, they have also always been used for festive occasions, political or commercial display (Auer, 2007). But despite their general significance, the concrete demand for lighting and the respective technologies varied over time and geographically. Although their basic uses have remained the same, some have become more important than others. Public lighting in post-war cities, for instance, has become very much oriented towards ensuring good visibility for car traffic.

The following historical overview fulfils two functions. First, it shows that lighting practices relate to *specific* circumstances and concerns. Innovation in urban lighting was as much shaped by technological progress and economic development as by local traditions, city life and politics. Second, it introduces the key actors, institutions, discourses and technologies of my research field and historic roots. As we will see, urban lighting has not always been an expert task and public service. The institutionalisation of urban lighting infrastructures has not only affected the economy of public lighting but also its visibility as a public issue.

The following introduction to my research field makes no claim to completeness, but offers a selective overview of four centuries of urban public lighting in Europe, from oil lanterns to

[399] „Vor der Ausbildung der Omnibusse, Eisenbahnen und Straßenbahnen im 19. Jahrhundert waren Menschen überhaupt nicht in der Lage, sich Minuten- bis stundenlang gegenseitig anblicken zu können oder zu müssen, ohne miteinander zu sprechen“ (Simmel, 1908).

LED luminaires. The chapter will thus pave the way for a better understanding of today's old and new public lighting practices and controversies and set the current innovation activity into perspective.

9.1 Early-modern Transitions: Cultivating the candle and light uses

Centrally organised public lighting practices and their various functions emerged in Europe as early as the second half of the 17^{th} century. Pre-modern urban spaces were not lit by stationary artificial lights but by mobile lamps and torches, carried by those who went outside after sunset. The primeval torch was superseded by oil lamps and candles burning with animal or plant products like waxes and oils (Brox, 2010).[400] The invention of the wick and oil lamp 'tamed' and domesticated the open flame, as described by historian Wolfgang Schivelbusch in his seminal work on modern artificial lighting in Europe (1988, p. 6).

Candles and oil lamps remained a luxury throughout the middle ages. The illumination of interior spaces was so costly that only few could afford it on a daily basis. What is fascinating about these pre-modern histories of artificial lights is that, although technologies and societies have changed fundamentally over time, the basic uses of light have not. City lights were and are still used for increasing people's sense of security and traffic safety. They are an integral part of social and authoritative techniques of control in and over urban spaces. Festive and decorative lights are signs of social and cultural distinction and also used as displays of power. Finally, it is important to note that uses of artificial lights might be instrumental and aimed at specific outcomes and functions,but the semiotic potential of light is very difficult to control. What people see and experience when confronted with light depends on both their physiological capacities, like eyesight, and their cultural backgrounds rooted in everyday habits, urban customs and professional routines. In addition,, light is semiotically ambivalent. Depending on how it is perceived, it can be medium, message or signal. Histories of artificial light can reveal both, the instrumental uses of lighting technology and the culturally contingent, situated semiotics of city lights.

[400] Spermaceti, oil extracted from the sperm of whales, was the preferred substance for oil lamps 'used in New York City's street lamps as early as 1792', reports Jakle (2001)

9.1.1 Torches and lanterns: Pre-modern lighting and urban life after dark

In pre-industrial times, work routines followed to the changing rhythms of sunrise and sunset and the seasons. Night-time, writes Roger A. Ekirch, 'embodied a distinct culture, with many of its own customs and rituals.' (2005, p. xxv). The historian describes in detail pre-industrial night-life and its dark, eerie, magic or mystic and intimate social spaces.[401] Hidden from daylight and from the public eye, rule and power were suspended. The poor and excluded could leave their shelters and hideouts. Under the veil of darkness, lovers met, friends or foes told their secrets and stories seized people's imagination.

Ekirch describes the nocturnal medieval urban street as an unruly, uncontrolled even antisocial space. 'It would be difficult to exaggerate the suspicion and insecurity bred by darkness.' (ibid, p. 8). Cities closed their gates in the evening. 'For most persons, the customary name for nightfall was 'shutting-in'. Schivelbusch compares the evening routines with the precautions taken on ships before a storm.

But mobility in medieval streets was not only restricted by nyctophobia—the fear of the dark—but also by municipal policies. They countervailed the absence of public surveillance and social control. Curfews—from Old French *cuevrefeu,* literally 'cover fire'—were imposed in cities throughout Europe. People caught on the street without an important mission or life-saving profession[402] risked fines or incarceration. 'From Copenhagen to Parma', city authorities blocked streets and pathways with chains at waist height; logs 'discouraged nightwalkers' in Moscow; chains blocked the Saône River in Lyon and iron barriers were spanned over the canals in Amsterdam (2005, p. 64). Jane Brox quotes an a municipal announcement: 'Let no one be so bold or daring to go about at night after the great seral of Saint Nizar without carrying lights, on pain of being put in prison and of paying sixty sous of Tours each time he is found to have done so' (Brox, 2015, p. 5).

The relation between mobility, safety and control also affects social distinction. 'In the night, all cats are grey', goes a saying. To humans, this privilege of equality was not granted. In the course of the 16th century, curfews were handled less restrictively. Yet, beggars, prostitutes and vagrants were still expelled from the night-time streets. In places like Venice, strangers

[401] Ekirch's history of pre-modern night-life covers different regions of the world but focuses primarily on Europe. It thus offers valuable details about night-life in medieval European cities, revealing cultural differences resulting from the local particularities and power structures.
[402] This excluded doctors, midwives, garbage collectors, latrine cleaners or mourners of the dead.

without an official approval by the magistrate had to leave the city at sunset. Women who ventured out onto the streets at night fell under a general suspicion of prostitution (Brox, 2015, p. 4).

The relaxation of the curfew was counterbalanced by measures aimed at increasing people's recognisability and hence the possibility of surveillance. In some places, municipal authorities forbade 'false faces' like visors and masks, big hats or hooded cloaks and restricted the possession of weapons (Ekirch, 2005, pp. 66-67). Whoever left the house after dark was required to carry a light in order to be visible and recognisable (Schivelbusch, 1987, p. 61).[403] But public safety and security issues[404] were only one good reason for lighting urban spaces artificially. Brox argues that it might have been 'in part for safety reasons' that authorities ordered stationary lights. Other reasons were commercial considerations and the belief that illuminations would support urban trade (2015, p. 6). This early-modern discovery of the so-called night-time economy also coincided with what historian Craig Koslofsky describes as 'nocturnalization' and an 'innovative use of the night' (2002).

9.1.2 Candle power: The 'nocturnalization' of early-modern court life

If fears of the dark create a demand for perennial lighting, the desire for leisure and pleasure spurs the demand for festive illuminations. Already in the Middle Ages, towns and cities had their shiny moments and well-lit places in churches, during religious festivals and observances.[405] But in the 17^{th} century, Renaissance staging techniques became part of Baroque court culture. No efforts were spared to bring the world to the stage. Richard Alewyn and Karl Sälzle point at two interconnected trends which mark the transition from Renaissance to Baroque court culture, namely the fact that festivities and cultural events were increasingly held indoors and postponed to late and night hours (1959). These shifts in place

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[403] Schivelbusch describes the lights as means to establish a fragile 'balance of power' on the night-time street. He quotes 'a psychoanalytical-poetic interpretation of fire and of candlelight' by Gaston Bachelard 'Everything that casts light sees' ('Tout ce qui brille voit') in order to outline the resulting mutual surveillance. While lanterns and torches put local authorities in the position to monitor nocturnal activities, individuals still had the freedom, despite the threat of punishment, to extinguish their lights and go out disguised by the dark. When street lighting was introduced in the 17^{th} century, that freedom was diminished by a municipal monopoly of control over the night-time city (Schivelbusch, 1988, pp. 95-97).

[404] I distinguish between *safety* as a *socio-material* category— a result or feeling of better control over (traffic) spaces—and *security* as a *socio-political* category—the result or feeling of being in control over other people (2013e).

[405] Ekirch points at the 'extensive use of giant beeswax candles' in Catholic churches, illuminated saints next to streets and spectacular 'assertions of Catholic hegemony in pre-modern times (2005:69-72). The lighting designer Eva-Maria Kreuz argues that churches were the brightest places at the time, as can be deduced from the large amounts of candles that churches received as tithes and donations (2012)

and time were facilitated by the emergence of secular celebration halls for balls, banquets, concerts, performances and plays.[406] 'The consequential development, by which the time of festivities was rescheduled from day to night, only became possible after one had learnt to illuminate these spaces accordingly' (ibid, p. 31, my translation). Hence, new architectures raised the demand for oil lamps and candles. Outdoor entertainment was offered in the form of sophisticated hour-long fireworks[407] or spectacular candle illuminations. In 1688, the park of Versailles was illuminated by 24,000 lights, presumably 'extremely costly' wax candles (Lotz, 1941; Schivelbusch, 1988, p. 7).

Koslofsky sees a 'nocturnalization' of European political culture in the new night-time activities and lighting technologies (2002, 2007, 2011). At the height of Baroque culture between 1650 and 1750, 'nocturnalization' shaped court life 'from architecture to cosmetics' (2002, p. 261). While Renaissance courtiers, kings and queens had reigned and celebrated at daytime, the absolutist Baroque kings 'lived for the state at daytime and for the court at night time' (Alewyn & Sälzle, 1959, p. 32). While the majority of the French working society got up at five in the morning, the French Sun King began his typical day at nine, long after sun rise, with the royal *levée* at Versailles.[408]

As the epithet 'Sun King' rightly suggests, Louis XIV's lighting practices stand out as a shining example of symbolic power and social control.[409] Presenting himself as the sun, he not only brought light to his subjects. Their night-lives were brought to light too, in a symbolic as well as literal sense. Aesthetic stimuli and excitement served as means to reinforce the king's power 'tied to the control of vision' and 'the passions of the gaze' (Hoffmann, 1997, p. 29).[410]

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[406] Among these newly built or rebuilt spaces were the *Herkules-Saal* (around 1600) at the Munich residence, the Whitehall Banqueting House (1622) in London, the Versailles Organgerie (1686) or the Dresdner *Zwinger* (1709).

[407] Such spectacles lasted for hours, had a narrative plot and were often accompanied by music. The theatre historian Helmar Schramm points out that these outdoor spectacles coincided with new developments in weapons and rocket technology and were thus experiment and artistic display at once. No clear line could be drawn between festive culture and experimental demonstration: 'Vulcano outbreaks and lightening, earthquakes and rainbows, wind and weather, the tides, sun, moon and stars were included in the world of experiment and of modelling' (2006, p. XV my translation).

[408] See Koslofsky 2002 and letters by Liselotte von der Pfalz…

[409] See *http://commons.wikimedia.org/wiki/File:Ballet_de_la_nuit_1653.jpg?uselang=de* for an image of Louis XIV, 'le roi soleil', aged fourteen, costumed as the sun at the occasion of his first appearance in a court performance of "Ballet de la Nuit" (1653). For more information see Koslofsky (2007, pp. 239-240). Schivelbusch (1988:86) also shows and refers to a medallion issued in commemoration of the first public lighting in Paris showing Louis XIV and the new lanterns (1988:86).

[410] As expressed in the political *Mémoires* of Louis XIV the king's subjects were meant to submit to the king's power not by force but seduced by pleasure: 'Our subjects are delighted to see that we [the king] love what they

The excessive use of light as an ‘equation of power’ could be observed all over Europe, ‘from Versailles to Vienna, Copenhagen to Turin’—reflecting ‘the grandeur of a ruler who could please courtiers, bedazzle subjects, and—at least fleetingly—conquer the darkness’ (Koslofsky, 2002, p. 748). ‘Nocturalization’ thus entailed an ‘aesthetisation of politics’[411] that allowed the absolutist rulers of Europe to signal their power and glory to both their subjects and other rulers—across territorial boundaries, and despite confessional division (2007, p. 268). It also involved new forms of social distinction. Not even every nobleman could afford to take part and hence be part of the ‘society of pleasures’ (Hoffmann, 1997). The extravagant and expressive life style at court was criticised for its wasteful use of resources, an ‘immoral use of time’ and for lulling people into complacency (2007, p. 242).[412]

Accoring to Koslofsky, the 17th century’s innovative night-time activities, including their candle feasts and fireworks, mark a ‘decisive step in the development of the modern night’ (2007, p. 236). As noble night-time activities generally increased they became more legitimate. The trend was also not confined to European courts but accompanied by new early-modern forms of urban social control.

9.1.3 Street lights: The birth of public lighting services

Early attempts to illuminate the streets of cities and towns showed little success as long as citizens were held responsible for the public good. In many places, residents were required to put oil lamps or candle-lit lanterns in their windows or in front of their houses. To reduce the

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love, or what they are most successful in. We thereby hold their hearts and soul’ (ibid, my translation). French original: “Cette société de plaisirs, qui donne aux personnes de la cour une honnête familiarité avec nous, les touche et les charme plus qu’on peut dire. Les peuples, d’un autre côté, se plaisent au spectacle, où au fond on a toujours pour but de leur plaire; et tous nos sujets, en général, sont ravis de voir que nous aimons ce qu’ils aiment, ou à quoi ils réussissent le mieux. Par là nous tenons leur esprit et leur coeur, quelquefois plus fortement peut-être, que par les récompenses et les bienfaits.” The *Mémoires* of Louis XIV (ed. Jean Longnon) in Hoffmann (1997:30).

[411] This term is used by Walter Benjamin to describe the spectacular staging of national socialism in the early 1930s in Germany including Albert Speer’s light domes ([1936] 1979)

[412] In 1784, Benjamin Franklin anonymously published a mockery letter on daylight in the *Journal de Paris* where he observed that the sun actually rises early in the morning—a revelation to the author who usually sleeps until noon. Being aware of this economical light source, he goes on calculating the money wasted in a city as big as Paris and concludes that there should be a tax ‘of a louis per window on every window that is provided with shutters to keep out the light of the sun.’ Furthermore, he suggests to ration candles for domestic use, re-impose a curfew and to ring the bells at dawn. He concludes that people might have overlooked that the sun ‘gave light as soon as it rose’ and that he has made a great discovery indeed. Because ‘it is impossible that so sensible a people, under such circumstances, should have lived so long by the smoky, unwholesome, and enormously expensive light of candles, if they had really known, that they might have had as much pure light of the sun for nothing.’ See online: http://www.webexhibits.org/daylightsaving/franklin3.html, last access 2013-02-28.

costs, streets were lit only for a few hours per night and according to the moon calendar.[413] However, in the absence of adequate and affordable light sources and public control, wind and weather made it difficult to keep candles and oil lamps burning and compliance was 'erratic' (Ekirch, 2005, p. 68; Hérleaut, 1917). As the following historic accounts suggest, the introduction of public lighting systems depended on powerful spokespeople. Absolutist rulers like Louis XIV in Paris and Augustus II, king-elector of Leipzig, were able to mobilise funds and manpower, that were necessary to implement the first early-modern street lighting systems. Furthermore, the above-described court culture also affected the public realm by opening up urban spaces to nocturnal traffic.

With the increased night-time activities of the noble society, the appeal of the nocturnal streets changed rapidly. 'Whereas not one leading European city before 1650 employed some form of public lighting, increasing numbers of municipalities did by 1700,' reports Ekirch (ibid, p. 73).[414] Koslofsky argues that glass-paned oil lanterns for street lighting were 'an innovation of the seventeenth century, both reflecting and promoting new attitudes toward the night and urban space' (2002, p. 745). 'Enclosed in glass, the flame had at last found its own space, separated from the outside world. According to contemporary accounts, it burned there with amazing calmness and steadiness.' (Schivelbusch, 1988). Modifications of the glass cylinder and wick soon increased the light output by feeding the flame with more oxygen.[415]

The first stationary, functioning public street lighting system was established in 1667 in Paris. After several attempts had been made throughout the 16th century, the French Sun King was again at the forefront of developments asserting his claim to power not only at court and in the spatial design of Versailles but also in the urban spaces of Paris.[416] The installation of candle lit lanterns was accompanied by a police reform in the course of which the muddy streets of

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[413] In Paris, in 1551, a parliamentary decree required citizens to illuminate their windows from November to January before six o'clock in the evening. In 1558, it was decided that lanterns should be installed at every street corner and be lit from 10 p.m. to 4 a.m. However, the chronicler commandant Herleaut observes that the regime was modified only one month later indicating that the first attempt had failed. But in vain: 'Unfortunately, the times were too troubled for succeeding in a project as considerable as the establishment of a permanent system of street lighting' (Hérleaut, 1917, pp. 132, my translation).

[414] Paris (1667) was followed by Amsterdam (1669), Berlin (1682), London (1683), Vienna (1688) (Ekirch 2005:73), Dublin (1697), Leipzig (1701), Lübeck (1704) and others: 'By 1700, street lighting had been established in Amsterdam, Paris, Turin, London, and Copenhagen; in French provincial cities; and across the Holy Roman Empire from Hamburg to Vienna. (Koslofsky 2002, pp. 744 and 754).

[415] The Swiss chemist Aimé Argand developed lamps with hollow wicks protected by chimney like glass cylinders. The Argand lamp was patented in 1780 and became very popular, especially for indoor uses (Schivelbusch 1988).

[416] As mentioned in footnote 21, parliamentary decrees concerning street illuminations occurred throughout the 16th century from 1504 onwards. Yet, with little effect as the decrees were quickly forgotten and the task was left in the hands of citizens who were reluctant to pay for lanterns (Hérleaut, 1917, pp. 130-134).

Paris were paved, too. Both were financed by a new 'tax of mud and lanterns' (*taxe des boues et lanterns*).[417] It was 'the only significant direct tax on householders in Paris under the Old Regime' (Koslofsky, 2002, p. 754). Furthermore, shop signs which reached into the streets and obstructed traffic or the view were removed for the benefit of public order. The citizens of Paris, supervised by draconic and arbitrary police controls, had to make sure that the candles in front of their houses burnt as long as they should. The money spent on street lighting was the second largest single item in the Paris police budget (Schivelbusch, 1988, p. 98; 103). Louis XIV's Baroque festivals were thus just one form of power display. The successful establishment of street lighting and the replacement of a variety of private lanterns by the king's standard design and policemen were another sign of power (1988, p. 86).

On a visit in 1698, the English traveller Martin Lister admired the Paris street lighting: The Paris lanterns 'continue to burn till after midnight' and 'through the whole of the winter, as well when the moon shines as when it is dark.' (Lister, 1823, pp. 48-49) In London streets were lit in accordance with the lunar phases and hence lay dark if the moon was clouded. Lister also describes the Paris fixtures in great detail: Square glass lanterns with 'candles in them, four of which weigh a pound…'[418] In 1700, more than 5,000 lanterns were installed and increased to 8,000 by the second half of the century. But the early-modern street lights did not illuminate the streets in the way we know it. Today Paris maintains approximately 150,000 light points.[419]

The comparison of light levels also reveals local difference in lighting practice. London streets were not only darker, there were also still privately lit until 1736 when contractors were commissioned to do the job on a district level. Comparing the two cities, Schivelbusch contrasts the absolutist lighting culture in Paris and an English 'lock-up culture'. The English trusted in door closing devices and were famous for their expertise in manufacturing locks and bolts (Schivelbusch, 1988, pp. 86-89).[420]

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[417] See Herleaut (140). He also describes the controversy around and evolution of this tax that went along with a reorganization of the *assemblées des quartiers* (1917:140-143).

[418] They were about two feet deep, covered with an iron plate, suspended over the middle of the street, twenty feet high, with secured ropes locked up in wooden trunks.(Lister, 1823). According to Herleaut, the lanterns were fixed to house walls. Aware of the inconsistency in historic accounts, Schivelbusch nevertheless concludes that the lanterns were hung 'like small suns, representing the Sun King, on whose orders they had been put up.'(1988: 86).

[419] See http://www.lemonde.fr/economie/article/2011/01/14/veolia-et-edf-en-passe-de-perdre-l-eclairage-de-paris_1465485_3234.html, last access 2013-03-01.

[420] 'It seems that in England—and later in the United States as well—security depended less on police surveillance, discipline and deterrence than on mechanical means such as locks and bolts.' (ibid: 88).

But local differences can also be observed in France. In Marseille, public lighting was only introduced in 1785. About one hundred years earlier the harbour city had opposed Louis XIV's will to introduce street lighting (Echinard, 2013). The spokespeople of the second city of France did not see the value and benefits of costly lanterns.

In Germany, Leipzig offers yet another model of public lighting.[421] After earlier, private initiatives by the merchants guild of the city (*Kaufmannschaft*) had failed, it was the absolutist king-elector Augustus II who presented his subjects with 700 oil lanterns on Christmas Eve of 1701 (Koslofsky, 2002, pp. 755-757). Service and maintenance lay in the hands of the city. But as street lighting taxes were not popular among citizens the mayor came up with an alternative. In Leipzig, everyone who entered or passed through the city at night was charged with a toll. Fees were collected at the city gate and there was enough night-time traffic, especially between the city and its suburbs, to cover the annual service and maintenance provided by four lantern masters and eighteen lantern keepers (Koslofsky, 2002, p. 757).

To conclude, organisational and technical advances in pre-industrial European cities appear closely connected with the above described 'nocturnalization' that spawned modern night life also outside the court (Schivelbusch, 1988). With the loosening or increasing neglect of curfews, mobility, commercial interests and social control became more important. On the other hand, control and maintenance regimes coincided with a general increase in government regulation as part of the emergence of the early-modern state (Ekirch, 2005, p. 72). Technological innovation thus occurred in locally different socio-political urban configurations.

9.1.4 Early public lights: Innovation, politics and opposition

In the second half the 17th century, the light output of the oil lamps was improved. Inventors like Edmund Heming in London and Jan van der Heyden in Amsterdam developed reflectors and methods to increase the level of oxygen inside the glass lamps. Especially van der Heyden's design became very popular in towns and cities across Europe.[422] With their detailed

[421] For an image of Leipzig street lighting in 1701 see http://museum.zib.de/sgml_internet/sgml.php?seite=5&fld_0=s0003382. Gustav Wustman (1891) depicts the street as a public place for various kinds of social interaction. The reading pedestrian in the left corner should not be taken too literally, the oil lamps cast only dim light on the streets, supposedly too dim to read. See also Koslofsky (2002: 758).

[422] The lamps were adopted in Dordrecht, Gouda, The Hague, Hamburg, Cologne and, without his authorisation, also in Dublin, Berlin and Leipzig. (Ekirch, 2005, p. 72; Koslofsky, 2002, p. 753). For an image see Koslofsky

accounts of luminaire designs and light outputs, travellers like Martin Lister and many others spread the new and provided technical information.[423] In the 18th century, the all-rounder, Benjamin Franklin, 'contributed substantially to oil lamp innovation' in Pennsylvania (Jakle, 2001, p. 21). Around 1740 he added a second wick and air vents to the lamp casket increasing the air updraft and hence the brilliance of the flames. In the 1780s, the Swiss natural scientist and inventor Aimé Argand could further amplify the brightness of the flame by introducing three modifications.[424]

Political incentives heralded the emergence of national systems of innovation (Freeman, 1995; List, 1841). In 1763, the Paris police and the *Académie des Sciences* held a competition aiming at 'a better way of lighting the streets of a big city considering brightness, maintenance and efficiency'. The desired result was achieved in the form of the so-called *réverbère*, an oil lamp burning with several wicks and two reflectors to focus the light. 'Like the first lanterns one hundred years before, *réverbères* were enthusiastically hailed as artificial suns that turned night into day,' reports Schivelbusch (1988, p. 95) Contemporaries suggested that 'the amount of light they cast makes it difficult to imagine that anything brighter could exist.'[425]

However, the effect was levelled out. As the light output increased, the number of lanterns was reduced considerably. The up to 8,000 light points of Paris were replaced by only 1,200 *réverbères* standing 60 meters apart, instead of 20 meters as they used to. As a result, the

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(ibid). In 1680, Frederick William I of Brandenburg-Prussia (1640-1688), had 1,600 lanterns installed in Berlin, Cölln and Werder at the citizens' expense. Van der Heyden's maintenance plan was also adopted (ibid: 754). In Leipzig, the local tinsmiths' guild took the Dutch design as a model for manufacturing 476 lanterns, the rest (222 lanterns) were manufactured in Dresden (ibid: 756). Production capacities could present an obstacle to innovation. In Vienna, for instance, the local tinsmiths were unable to manufacture the ordered amount of lanterns (Koslofsky, 2002, p. 754)

[423] I would not be surprised if the enthusiastic and demanding tone of these reports had stimulated local demand and the diffusion of technological innovations. But they are more than technical reports as they also include subjective, often culturally tinted observations, which serve as an excellent source for historical and cultural reflection.

[424] First, he developed a hollow type wick so that the burning surface exposed to air was much larger. Second, he enclosed the burning wick-tube in a cylindrical glass producing the effect of a chimney. Third, the Argand oil lamp contained a mechanism for varying the length of the wick and thereby the size of the flame and its light output (Jakle, 2001, p. 22; Schivelbusch, 1988, pp. 11-13).

[425] The French writer Louis-Sebastian Mercier thought that the city was now 'extremely brightly lit', but only to get accustomed to them and find them inadequate later: 'These lights cast nothing but darkness made visible… From a distance they hurt the eyes, from close up they give hardly any light, and standing directly underneath one, one might as well be in the dark.' (Schivelbusch 1988: 95, from Herleaut). This might have been due to an inhomogeneous light distribution with harsh contrasts between darkness and brightness to which the human eye has difficulties to adapt. Schivelbusch draws the conclusion that 'it is impossible to reconstruct exactly how bright the *réverbères* really were' one could still assume that they illuminated sections of the streets of Paris quite effectively (ibid: 95).

streets of Paris were still dark after nightfall and the services of linkmen with mobile lights were still indispensable. The innovation thus did not improve the lighting but made it more efficient and easier to operate. Beneficiaries of the improvements were the authorities and technicians rather than the users of urban spaces.

The asymmetry between the authorities and the citizens was also evident in acts and practices of opposition and destruction. Schivelbusch takes the popularity of lantern smashing as a sign of subversion and revolt against the absolutist French king, culminating in the barricade fights of the French Revolution.[426] 'Destroying lanterns in the seventeenth and eighteenth century offered the additional satisfaction of symbolically unseating the authority they represented: the darkness that prevailed after the lanterns had gone out stood for disorder and freedom.' (ibid, p. 98) Accordingly, punishment was harsh in France.[427]

The popularity of lantern smashing also shaped public lighting designs. *Réverbères* were positioned higher than their predecessors to move them out of the reach of vandals. Similar considerations shape luminaire designs to the present day.

Opposition against public lighting also reflected in citizens' reluctance to pay the respective taxes imposed on them by rulers (Ekirch, 2005, p. 74; Koslofsky, 2002, p. 756). Again, this can be an indicator for the limited practical use of street lights, still considered as a luxury in the 17th and early 18th centuries to the advantage of urban elites who could afford and enjoy the new social activities after dark.

The tensions linked to the organisation of early public lighting also have a cultural dimension. While in France and Germany court culture was a driver of new exclusive social practices, the English social elites partook in an emerging 'polite' club culture in London and other urban centres (Sennett, 1969)(Hutter, consuming politeness). Focusing on northern English towns, the historian Jon Stobart argues that 'a prosperous middle class of industrialists, merchants, tradesmen and professionals' contributed significantly to urban development and design,

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[426] As Schivelbusch outlines, the symbolic meaning of lanterns also reflects in the French language. The verb *lanterner* used to refer to 'doing nothing' or 'wasting one's time'. In 1789*, lanterner* came to signify 'to hang someone from a lantern' (ibid: 100). While in the first sense of the word the connotation to daily street life is stronger, the revolutionary new usage of the street furniture is highlighted.

[427] During the Ancien Régime, lantern smashing was a criminal offense in Paris and severely punished. In London, however, it was only considered as disorderly conduct (ibid: 99). Koslofsky refers to edicts through which municipal authorities all over Europe condemned such vandalism. For example in Berlin (1702), Frankfurt am Main (1711) and Dublin (1716) 'The authorities in Vienna even 'threatened to cut off the right hand of anyone caught damaging a street lantern.' (2002: 760)

including the installation of street lighting.[428] In 1730, lanterns illuminated the streets of Bristol, Hull, Liverpool, Birmingham and Sheffield. Stobart links the new ‘cultured urban life’ to a ‘need for social integration within the growing middling ranks of these towns and their desire to differentiate themselves from ordinary working people.’ (Stobart, 2002, p. 473) The bourgeois efforts in urban design in the second half of the 18th century echoed the aesthetic politics of Baroque court culture in their own language and cultural expression. They also paved the way for the popularisation of urban night life.

Before I move on to histories of industrial city lights, I will briefly sum up and emphasise four points. First, early public lighting in European cities was facilitated by technological improvements. As each and every flame had to be lit and consumed costly raw materials, technological improvements could reduce the costs considerably. The better the light output, the less light points were needed. The light levels were not comparable to what is considered safe and normal today though. Second, pre-industrial city lights were still considered a luxury and, as such, opposed or demanded by urban publics or elites. Pre-industrial public lighting was not yet taken for granted. Symbolic acts of destruction and the opposition tothe tax on the one hand, and social elite’s initiatives to enhance technological development and the introduction of street lights on the other, suggest that early-modern lighting practices were charged with socio-cultural meaning and political significance. Promoted and opposed as they were, early-modern street lights can be described as a public matter of concern even before they were institutionalised in the process of publically funded civil engineering projects and municipal services in the course of the industrialisation. Third, and finally, the above-described early-modern joint technological efforts and civic oppositions already show the signs of an increasing divide between innovators, technology users and affected publics. While technology users and developers evaluate street lights in terms of efficiency and utility and begin to engage with it systematically, the supposed beneficiaries relate affectively and in culturally contingent ways. Citizens’ perception of new and brighter lights and their appreciation of lighting practices find their expression in rather unsystematic subjective assessments of light quality, movements of political opposition or acts of vandalism. These

[428] ‘Assemblies were probably the most common activity, with ballrooms being included in many town halls during the middle decades of the century and purpose-built rooms following in several towns. Pleasure gardens and walks were also established in many commercial towns, and theatres and music concerts became increasingly common…’ (Stobart, 2002, p. 473)

different, group-specific modes of engagement with public lights became even more apparent with the industrialisation.

9.2 Industrial transitions: Building public lighting systems and expertise

The industrialisation fundamentally changed European cities and their day-and-night rhythm. New spatial arrangements were accompanied by new temporal regimes. Technological inventions, new institutions and organisations allowed urban society to 'colonise' the night (Melbin, 1987). Lighting and its infrastructures also transformed in the course of urbanisation and in line with technological developments. The first fundamental change was the introduction of gaslight, well a hundred years before the electric light bulb again changed the night-time image and atmosphere of nocturnal urban spaces. The new industrial way of lighting cities thus irreversibly changed the relations between light, cities and the various users of light and technology.

In contrast to candles and oil lamps, gas was intangible and its infrastructures widely distributed, complex and more difficult to comprehend. Their light output was not determined by one technical artefact, but by the operation and supply of large technical systems that spread over long distances (Schivelbusch, 1988). The engineer and gaslight pioneer Samuel Clegg highlights the innovation by drawing a comparison between old and new technologies:

'The whole difference between the greater process of the gas-light operation and the miniature operation of a candle or lamp, consists in having the distillatory apparatus at the gas-light manufactory, at a distance, instead of being in the wick of the candle or lamp […]. The principle of the gas-light manufacture is therefore precisely similar to the general mode in which all light is produced: it is simply conducting on a huge and general scale the natural operations of ignition.' (Clegg, 1853, pp. 99-100)

The brightness of a gas lamp depended on the quality of coal gas, the burner and the maintenance of the lamp (Clegg, 1853). With the adjustable and dimmable gas flame, the formerly rather fixed relation between light and lighting technology was dissolved. As a result, light levels and lighting practices became subject to efficiency considerations and evaluations. Yet the tools for such evaluations did not yet exist. With the development of metering devices, photometric instruments and standards, light was made quantifiable (Otter, 2008).

The new epistemic practices and disputes regarding the measurement of light levels had a twofold effect. On the one hand, the relationship between light and space was inscribed and embodied in new forms—photometric values as well as measuring routines that required professional vision and expertise. On the other hand, this also spurred scientific investigations on light and its effects. Scientific debates about photometry or the non-visual effects of lighting have continued since then. They also built the basis for technological innovation in lighting as the LED development strikingly illustrates.

Finally, the industrialisation of lighting and the commodification of light perfected the division between those producing light and those using it on a daily basis. With gas, light became widely available and lost the status of being a luxury good. Squandering and extravagant candle illuminations were replaced by an economy of light. As city lights became commonly available, they were soon taken for granted.[429] Yet, while people used more and more light, they were less and less involved in practices of lighting. As authoritarian systems of public lighting gave way to a complex public-private organisation of large technical systems, the illumination of urban spaces became an expert task. As the following section will show, the 'invisibilisation' of lighting technology and infrastructures is part of different engagements with light and lighting technology between those who light and those who are affected by the light.

Accordingly, the following three sections focus on the establishment of large urban socio-technical lighting infrastructures (9.2.1), on the establishment of expert lighting and control systems (9.2.2) and on the growing divide between public and professional evaluation of light technological innovation (9.2.3).

[429] Artificial lighting has, in the words of the French sociologist Bruno Latour, turned from a 'matter of concern' into a 'matter of fact' (Latour, 2009). Yet as historical and present examples show (Meier et al., 2015), it is transformed back into a 'matter of concern' in the face of technological innovations like the incandescent light bulb and LED light (Binder, 1999; Thomas P. Hughes, 1983), special events like festivals or black outs (T. Edensor, 2012; Géraud, 2006; David E. Nye, 1990, 2010) and new discourses (J. M. Deleuil, 1995; Krause, 2015).

9.2.1 Gaslight: Lighting infrastructures for industrial cities

In the course of the 18th century, the brightness of early-modern reflector lamps was far exceeded by a new light source. The discovery and exploitation of the 'spirit of coal' was fuelled by economic considerations and closely linked to steam engines and industrial production. With gas, the pre-industrial logic of absolutist representation and police control gave way to the 'invisible hand of the market', as can best be observed when looking at England, the cradle of industrialisation.

The 'elastic inflammable air' (Clegg, 1853, p. 2) had already been discovered long ago, but only in the second half of the 18th century did researchers' and experimenters' efforts show their effects (Van der Stock, 1998, p. 137). The first gas-lit spaces were industrial production sites. In 1802, years of tests and trials culminated in a spectacular public display of Bengal gaslights on top of a Birmingham factory[430] on the occasion of the general illuminations of the Peace of Amiens. In 1807, London's Pall Mall was the first gas-lit street.[431] The demonstration was followed by a gas-lit pavilion in St. James's Park in June 1814, celebrating the defeat of Napoleon (Clegg, 1853, pp. 6,19).

The English king was only an observer of these early technological tests and displays. This time, the driving forces behind the invention and its exploitation were inventors and entrepreneurs who had recognised the economic potentials of gaslights. Steam engines and machines needed no sleep, but workers needed light if they were to work in shifts. In winter, the lack of daylight raised production costs. Using gas, a by-product of the coal industry, for the illumination of work places not only reduced the cost of lighting but also improved the light levels significantly. The economic advantage of gaslight over candles and oil lamps had been meticulously listed in 18th century articles on the subject.

The improved efficiency was a compelling argument for risking the big upfront investments and performing the technological transition from luminaire to infrastructure. In his seminal 'practical treatise'[432], gaslight pioneer Clegg outlines in detail the cost benefit of gaslight when compared to different types of candles or oil lamps. While the latter 'will not prevent

[430] The Bolton & Watt Soho Foundry (Clegg, 1853).
[431] See Clegg (1853) and http://www.wired.com/science/discoveries/news/2008/01/dayintech_0128#, last access 2013-11-05.
[432] The full title is 'A practical treatise on the manufacture and distribution of coal-gas, its introduction and progressive improvement; illustrated by engravings from working drawings, with general estimates.' (Clegg, 1853),

waste', the combustion of gas consumes a by-product of coke production. Clegg also points to the organisational benefits arguing that 'the annual outlay will be known' as the implementation, operation and service costs are calculable (ibid, p. 104).

With gaslight, public lighting reached a different scale. Pre-modern lighting had become more expensive with each additional lamp. Gas lighting incentivised the construction of large technical systems since more light points paid off the large up-front investments more rapidly.[433] The linear function of light production and costs was overridden and replaced by economies of scale. Large numbers of lights are proportionally cheaper than few since the major part of the investment goes into the erection of gasworks and the establishment of infrastructures. Furthermore, a high density of light points was more economic than a geographically wide-spread system, thus making the new light particularly attractive for densely populated urban spaces.[434] But again, urban configurations differed. Gaslight was even cheaper in mining areas where cities could profit from lower gas prices.[435]

In the early years, gas production and lighting technology was immature and unsafe (Tomory, 2009). Capital was needed for the establishment of gasworks and networks (Clegg, 1853). To reduce the risk of high up-front cost and technological failure, the implementation of the innovation highly depended on the establishment of public-private partnerships and the creation of legal frameworks. Gas utilities were among the first vehicles for public investments in industry (Bazerman, 1999, p. 149). In 1813, the Westminster Gas-light and Coke Company was founded. Backed by Parliament and a Royal Charter, the company established the first public gas works with an original capitalisation of £1 million (about £9 billion at 2005 prices) in 80,000 shares.[436] The gas works mark the beginning of a new era of public lighting services in public-private hands.

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[433] Schivelbusch points out that domestic gaslighting transformed the relation between households and community. While pre-industrial lighting was the responsibility of single households or the neighbourhood, gas lighting was provided by private companies for large districts or the whole city and was regulated on a national scale.

[434] 'The supplying of light to the street or parish lamps alone can never be undertaken with economy in any district, the most beneficial applications being in those situations where a quantity of light is wanted in a small space. Where the light is required to be more diffused, the profit is less, owing to the greater extent of services and fittings.' (Clegg, 1853, p. 107)

[435] Clegg concludes that the 'most economical arrangements' depend on the particular local situation (ibid).

[436] http://en.wikipedia.org/wiki/Gas_Light_and_Coke_Company, 2013-11-14. Before gas could flow a number of problems had to be overcome. Clegg recalls the difficulties of the innovation process—not without self-praise: 'From the time of the formation of the Chartered Gas-light and Coke Company to the year 1813 (when Mr. Clegg was engaged as engineer), the works had been entrusted to Messrs. Winsor, Accum, and Hargraves. It will appear an enigma at the present day how their attempts to construct a gas apparatus could so utterly have failed;

The establishment of 'networks of gas' involved not only new institutional arrangements but also depended on a series of technical inventions in order to overcome systemic problems, comparable to what Thomas Hughes later described as 'reverse salient'. Retorts were developed for distilling the gas and getting rid of bad fumes.[437] The lack of pipes for conveying gas from the distilleries to gas holders and the places of consumption was another problem. The plan was to build an underground system of mains and branches but:

> '…no service-pipes were to be bought at all. The great cost of making sheet-iron or copper tubes was very serious. Many manufacturers were applied to make pipes, but without success; they would not expend money for machinery to construct anything connected with such a "foolish, unlucky thing" as Gas!' (Clegg, 1853, p. 20)

The problem of adequate materials for miles of mains was not only economically relevant.438 It was also an environmental issue as leakages poisoned the soil and groundwater (Malherbe, Dufeillay, Papin, & Trastour, 1855; Schivelbusch, 1983, p. 44).

By the 1820s, most cities had gasworks and 'several hundred miles of underground gas mains supplied more than forty thousand public gas lamps for the streets of London' (Brox, 2015, p. 14). By the mid-19th century, most English towns were provided with gas. The development was spurred when gas prices fell between 1830 and 1880, transforming townscapes above and below ground.[439]

From 1820 onwards the technology spread in Europe. As Leslie Tomory remarks, it seems like irony that after basic research on gaslight had been done by French and German chemists, the technology matured in England before it was adopted on the continent (2009, pp. 584-

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but discredit is not attached to those gentlemen, for it must be remembered that nothing had yet been done to which reference could be made all was new: every machine had to be invented, and the workmen instructed in its use.' (1853, p. 15)

[437] To reduce negative environmental side effects, purification processes were introduced to clean coal gas from 'noxious elements' like tar, carbonic acid or ammonia (Otter, 2008, p. 138) and later also to draw impurities from the vapour.

[438] The Chartered Company thus resorted to recycled water pipes. There were also wooden pipes, 'made from old gun barrels or hollowed tree trunks […] The Cambridge University […] experimented in the 1840s with tile mains, which, predictably, leaked.' Laying mains was tricky, too. In some places they had to be stabilised by clay to prevent their sinking through the earth. Furthermore, some houses were not fit to carry the new domestic infrastructures or tenants would de-install the surface mounted tin pipes when they moved. (Otter, 2008, p. 139)

[439] Otter describes how the new infrastructures above ground changed urban spaces also at day time: 'Progress was physically measurable by the number and size of gas holders […] The languid rise and fall of these rusting pistons became part of the daily rhythm of the industrialized metropolis. Underground, the network of mains expanded so rapidly that precise geographic knowledge of the system became impossible.' (2008, p. 151).

586). The first French and German gas companies were founded with English capital and know-how. The *Compagnie Anglaise*, the largest gas provider in Paris, was founded in 1821. In Lyon, gaslight was introduced in the 1830s but it was only in 1847, after the city was granted an official monopoly,440 that the gas network stretched out beyond the city centre (J. M. Deleuil, 1995).

In Berlin, the Imperial Continental Gas Association (I.C.G.A.) started to operate in 1826. The first street illuminated by gaslight was Unter den Linden. The event raised public attention and was attended by curious citizens and the press. In the course of the following year the I.C.G.A. installed 1789 gas lanterns. Its contract with the city ended in 1846 when the city took over gasworks and public lighting (Grimm, 2012, pp. 22-24).

The establishment of municipal gas infrastructures transformed the look and feel of cities. For the first time, public spaces were truly lit.[441] Eye witnesses of gaslight installations all over Europe found that gaslight 'replaced the sun', was 'too pure for the human eye' and 'completely penetrates the whole atmosphere' appearing 'natural as daylight', clear, bright and colourless (Schivelbusch, 1983, p. 22). In the course of the 19th century, gasworks and gas networks became standard urban infrastructures.

9.2.2 Light control: Governance, regulation and measuring techniques

While historians link early-modern lighting to political issues like royal representation and urban surveillance regimes, the new industrial lighting is associated with new forms of control. Looking at England, the historian Chris Otter shows how new lighting practices coevolved with new forms of urban design. The Victorian government, he argues, turned its 'myopic eyes away from its subjects and onto the mammoth technological systems that sustained them' (2008, p. 134). The need for distributed control grew with 'the need to regulate large technological systems that, despite the best intentions of engineers, failed to regulate themselves.' (p. 172) Otter describes the new regulatory regimes in terms of

[440] In London, parliamentary acts forbade gas companies to monopolise the urban gas supplies for the metropolis (Otter, 2008).
[441] Samuel Clegg recalls: 'The contractors who had supplied the oil-lamps were loud in their complaints. One of these, when told […] that his lamps gave no light, replied that this was not in his contract, which only stated that they were to be lighted from sunset to sunrise. This was literally the case,--lighted they were, but light they gave none.' (Clegg, 1853, p. 18)

‘inspectability’. In the Victorian age, public lighting was no longer granted by authoritarian control and police patrols but by expert inspection and self-regulating technical systems.

The gas infrastructures needed constant care and a number of inspection devices were put into place to supervise the socio-material system. Gas holders needed inspection as they could explode, which was a major public concern in the early years of gaslight. Pipes were checked for leakages. Inbuilt syphons collecting moisture and tar were regularly emptied, some ‘every couple of weeks’ (p. 139). As efficiency was crucial, new technical devices like self-regulating feedback valves, governors and meters were developed to regulate and measure gas consumption.[442] These material inbuilt devices made industrial public lighting not only easier, they made it possible as they were indispensable for the functioning and operability of the large distributed and partly inaccessible gas lighting infrastructures (ibid, p. 142).

Otter links his ‘inspectability’ thesis to liberalism and new regimes of urban governance and control. In 19th-century Victorian cities, draconic police force was replaced by inbuilt or internalised self-control, which applied to both the use of lighting technology and the newly lit urban spaces. ‘Individual mobility and orientation were enhanced by the illumination of clocks and streets.’ (ibid, p. 153) In this situation, public lighting added to the distributed soft power of publics as it facilitated mutual social control via glances (Schulte-Römer, 2013e).[443]

But how much light was enough? The light output of gas burners was not determined by the lamp design. Gas flames and hence light levels could be regulated by feeding more or less gas. The new technology thus also called for a re-evaluation of light quality and levels. Yet at the beginning of the 19th century, ‘[t]here was no defined standard against which to measure gaslight, no fixed unit of measurement, and no consensus about the kind of apparatus one should use to make the comparison’ (2008, p. 136).

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[442] ‘Feedback and measurement machines were also used to record quantity of consumption and, hence, charge customers. This was not a problem with candles and oil lamps as […] the rate of consumption was tangible and visible’ (Otter, 2008, p. 143). In the early years of gas lighting, inspections had been used to regulate the domestic use of gas. At the time, customers had flat rate contracts with their urban gas providers, which ‘often led to accusations of prodigal or illicit usage’ (Otter, 2008, p. 143). Inspectors therefore patrolled the streets to detect wasteful uses of gas, e.g., open gas taps or lights that burned beyond the prescribed hour (ibid: 144). As this form of socially control was inefficient and personnel-intensive, inspectors were replaced by metering devices. By 1840, customers paid for the gas they consumed and flat rate contracts were replaced by the metering system. Inspection practices shifted from checking on people and their lighting practice to checking instruments and technical devices (ibid: 146).

[443] The link to the notion of the panopticon is obvious (Bentham, 1791; Foucault, 1994 [1975]). Yet Otter dismisses the notion of panoptic power stressing the distributed nature and liberal spirit of the ‘Victorian eye’.

Subsequent scientific debates ended with the establishment of the *candle standard* as a measuring unit for the light output of lamps.[444] In London and also in other English cities measuring stations were erected in close proximity to the gasworks where photometrists kept track of the brightness of street lamps.

The rise of photometry raised epistemic problems, particularly two issues that are still relevant today. The first problem concerns the involvement of the human eye and brain in scientific procedures of measuring light. The very fact that the human eye reacts and adapts to light rendered visual perception as part of scientific measuring techniques problematic. To improve the validity of their photometric measurements, 19th century lighting experts resorted to standardising the bodily performance of the measuring person.[445] Since then, physiological research and experiments have added to the understanding of human vision and light perception. Inscribed in standardised instruments and calculations, this knowledge is at the heart of photometry and the scientific evaluation of light quality and levels of brightness.

Yet early photometric efforts raised a second epistemic problem that concerns the tension between laboratory and reality or in other words, the tension between replicable and practicable measuring techniques (Gooday, 2004). When gaslight started to change the nightscapes of cities and urban night-life, there were neither standards nor instruments for measuring light *in space*. Otter argues that the development of portable measuring devices that could be used outside laboratories was 'absolutely integral' to the municipal management of public lighting. After all, light levels depended not only on the choice and regulation of light sources but were also affected by dirty lantern glass or light-absorbing environments like trees or dark surfaces. The 'foot-candle', later renamed *lux*, was the first step towards measuring the so-called illuminance of light sources that is the visible light shed on a certain space as perceived by the human eye.[446]

The industrialisation thus changed the production of light and the ways in which innovations and their practical and social value were measured and discussed. The new ways of calculating and counterbalancing the benefit, cost and profits of gas lighting were performed

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[444] Otter also describes in detail how rudimentary the candle standard was. The quality of the candles and wicks used for these measurements were hard to define. Furthermore, the measurement only accounted for the light that a lamp emitted in one particular angle.

[445] To avoid bias, photometrists should avoid thinking and trust their spontaneous sensations. For more objectivity, they should work in pairs and perform fast and similar movements (Otter, 2008).

[446] Accordingly, the 19th century's advances in photometry not only built the basis for calculating light levels but also enabled gas engineer-entrepreneurs to promote their inventions and to claim improvements in public.

within an innovation system marked by distributed action and liberal market regulation that corresponds with Adam Smith's notion of an 'invisible hand' (1937).

Developed as an efficient means of illuminating work places, the new light source soon started a consequential social transformation that eventually produced the famous 'city that never sleeps'. However, before it was taken for granted and invisibilised, the new lighting technology raised a number of issues, including debates on public health[447], its negative environmental effects and epistemic debates on appropriate light levels, their measurement and standardisation. The invisible gas could be experienced in different ways, as a burning flame, its side-effects (smell and headaches) or a measured value. Yet, professionalised and specialised as gas lighting was, the experiences of citizens and experts diverged. While the latter got immersed in their routines in a socio-material system, the users of public space got used to the illuminated night-time city. 'In the middle of the nineteenth century a new word was minted', reports Jane Brox (2015). The word was '*nightlife*'. With gas, city lights had diversified. Pipelines were first provided in city centres and commercial streets where shops, theatres and pubs were lit up, too. In gas-lit neighbourhoods brightness 'increased exponentially, which in turn fed the vitality of the streets' and people grew accustomed to the higher light levels (Brox, 2015, p. 18).

In this situation, the technological displays of the next innovation in light offer valuable historical insights in the public perception of the incandescent light bulb and its impact on 20th century urban spaces.

9.2.3 Invisible light: Black-boxed technology and social differentiation

The introduction of gaslight and its large technical infrastructures had a twofold, seemingly paradoxical effect. While nocturnal spaces became brighter and night-life more visible, the means of lighting were rendered invisible. On the one hand, the act of lighting came to draw less and less public attention. The gas flame burnt steadier than a candle or oil lamp and required less constant care by the users. Gasworks were improved in response to public fears and discussions on health and safety risks and people gained trust and got used to them. On the other hand, gas infrastructures were also removed from the public eye. Mains and pipes

[447]Domestic gaslight smelled and polluted the air to a degree that it caused headaches and worse. The purification of the coal gas solved the problem only partly. When electric lighting was introduced, its clean brightness was therefore an important advantage over gaslight.

were buried underground and the gas production moved from the city centres to peripheral areas. Furthermore, citizens were freed from the task of lighting their cities. As the distributed production of light was decentralised and became technically more complex, experts took over.[448] In 1871 the *Engineer* reports: 'The public know nothing of the battle between gas and air which was going on beneath their feet; and when the city burst into its wanted illumination at night none but the initiated were aware that the gas which burned so brilliantly […] had been manufactured in the bleak country on the rivers side, some eight or nine miles away.' ("The Opening of the Beckton Gasworks," 1871, p. 95; Otter, 2008, pp. 151-153). 'It must be understood' that gas works should be 'designed and executed with skill', argued Clegg in his 'practical treatise'—a skill that 'can only be learned by practice.' (1853, p. 104) Emphasising the ignorance of laypeople in the early years of gas lighting he tells an anecdote:

> 'Gas-lights, being then a novelty, created much surprise and admiration; indeed, a lady of rank was so much astonished and delighted with the brilliancy of a lamp fixed on the shop-counter, that she begged to be allowed to carry it home in her carriage, offering any sum for a lamp so far superior to any she had before seen: *this is a proof how little the nature of gas-lighting was at that time understood*.'(Clegg, 1853, pp. 15, my emphasis)

Gas lighting thus further separated the social worlds of expert technology users and citizens as lay beneficiaries, affected parties or light users, as I call them. While the latter noticed lighting technology only when the light distribution or brightness in urban spaces changed, the first were directly affected by changes in work routines and the above-described delegation of light control to technical devices like switches, valves and meters. While the audience celebrated the new light, the lamp lighter feared to lose his job.

In 1838, when large parts and several hundred miles of underground gas mains supplied thousands of public gas lamps in London (Brox, 2015), Charles Dickens stages an encounter of technology user and light user. On his routine tour, lamp lighter Tom meets Mr. Stargazer, a London resident who is out on the street to witness a comet. Tom tells Stargazer that 'he wasn't born' as a lamp lighter but had ladder and light from his uncle. When gaslight was first talked of that uncle did not believe it, recalls Tom:

[448] The first gas engineers had not only technical and material knowledge. Like the system builders of electric infrastructures, they were also capable of managing construction works and controlling their projects financially. After public displays had been successful, the creation of public private companies facilitated the large infrastructural investments (Schivelbusch, Clegg: 15; etc.).

‘… “There’s no such a thing,” he says “You might as well talk of laying on an everlasting succession of glow-worms!” [But…] when the experiment was made of lighting a piece of Pall Mall, and he had actually witnessed it, with his own eyes, you should have seen my uncle then!

MR. STARGAZER. So much overcome?

TOM. Overcome, sir! He fell off his ladder, from weakness, fourteen times that very night; and his last fall was into a wheelbarrow that was going his way, and humanely took him home. “I foresee in this,” he says, “the breaking up of our profession; no more polishing of the tin reflectors,” he says; “no more fancy-work, in the way of clipping the cottons at two o’clock in the morning; no more going the rounds to trim by daylight, and dribbling down of the *ile* on the hats and bonnets of the ladies and gentlemen, when one feels in good spirits. Any low fellow can light a gas-lamp, and it’s all up!”…’ (Dickens, 1838)

The play illustrates two aspects that are important for my work: First, lamp lighter and resident meet and exchange accidentally on a public street. Second, the initially-mentioned gaslight test or display in Pall Mall (9.2.1.) presents an important point of reference for both. While the resident refers to it as a sensation—‘so much overcome?’, the lamp lighter’s perspective is quite different as the new technology means ‘the breaking up’ of his profession.

Public test and show cases thus constitute unique locales for unmediated exchange between experts and laypeople in situations in which both are simultaneously affected by the same light technological installations. The 1807 gaslight experiment in Pall Mall meant different things to different actor groups. For inventor-entrepreneurs it was a test and show case. For lamp lighters an existential threat and for lay urban audiences a spectacle of innovation. The astonishingly bright and steady light stirred a public attention that was readily taken up by the mass media and cannot be underestimated in the innovation process. It facilitates spontaneous sensuous involvement and evaluation that can only take place as long as the new lights are still perceived as surprisingly different, that is before they become taken-for-granted and invisibilised. In terms of public involvement, the Pall Mall technology trial thus differed from the subsequent large-scale implementation of urban gas lighting infrastructures. It created a situation in which even lay people could evaluate the performance of the new technology by comparing the new light to what they knew: “Wauns, what a main pretty light it be: we have nothing like it in our Country.”, exclaims a character in an engraving by Thomas Rowlandson

(1809), while others comment on the innovation in terms of its technical, environmental and social effects.[449]

The same applies to the next technological innovation. When about one hundred years later, public displays of electric lighting were presented on fair grounds, during festivities and on public streets (Binder, 1999)(Nye…), the new light was received and perceived with amazement by its urban audiences.

9.3 Modern transitions: Electric lighting for 20th century cities

Gaslight paved the way for electricity. By the late 19th century, gas lighting had achieved what Charles Bazerman describes as ‘a robust social presence’, a technology perceived as ‘a unitary social fact’ aggregating meanings in configurations of discourses, activities and representations (1999, p. 144). These configurations were mostly urban and marked by the described distinction between experts and lay audiences. Citizens were used to illuminated public spaces and large distributed urban networks operated by experts.

Again, the evolution of electric lighting cannot be understood independently of its local institutional, cultural, entrepreneurial and public urban configurations. Early electric lighting fixtures varied in Europe and North America. They were also differently evaluated. While stationary oil lamps had been promoted by European kings and emperors and gas lighting by English industrials, the future of electric lighting began in the late 19th century in the United States. There, electric system-building started with a so-called inventor-entrepreneur, Thomas A. Edison, as a key figure.

Edison’s success in innovation makes him a popular object of innovation studies. As a ‘spokesperson’ of electric lighting (Akrich et al., 2002b) he understood perfectly well how to translate his goals into the languages of investors, mass media and potential customers and users of light bulbs (Bazerman, 1999). His innovation management has been studied in terms of ‘distributed creativity’ (Miettinen, 2006), system-building (Thomas P. Hughes, 1987; Thomas.P. Hughes, 1979) and ‘robust’ urban infrastructural design (Hargadon & Douglas, 2001).

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[449] http://commons.wikimedia.org/wiki/File:A_Peep_at_the_Gas_Lights_in_Pall_Mall_Rowlandson_1809.jpg

In this section the focus is primarily on the material and immaterial strategies that facilitated the positive valorisation of the disruptive innovation. They not only include design and communication strategies but also timing and the choice of locales for innovation displays for engaging publics and investors in innovation. Historic accounts of early public displays of incandescent lighting thus underline the important role of lay and expert audiences for innovation, that is the electriciation (Binder, 1999). Like gaslight, electric lighting required the installation of large technological infrastructures built with up-front public investments and expert organisation. Unlike gas, electricity did not explode or pollute the soil and water. The transformation from gas to incandescent lighting thus meant both a continuation of taken-for-granted urban practices and structures and their improvement.

The first electric light source was not the incandescent light bulb but the arc lamp (9.3.1.). Thus, the introduction of an electric lighting system offered an alternative to two very different competing technologies (9.3.2.). Finally, the electrification in industrialised countries was accompanied by new forms of mobility and architectural design that fundamentally changed the planning environment in the 'modern city' (9.3.3.).

9.3.1 Arc lamps: 'Dazzling' and 'moon-like' but not convincing

Carbon-arc lighting is based on the principle of electric discharge. In the first arc lamp, bright light was produced between oppositely charged carbon rods with a small gap in between. Contemporary discharge lamps use different materials, like tungsten electrodes surrounded by gas that then lights up when ionised, and are widely used for lighting public streets (9.3.3.).

First experiments with carbon-arc lamps were performed by the English chemist and inventor Humphry Davy already in the early 19th century. The first arc lamps were developed for miners in English coal pits. Electric power from batteries was applied to facing charcoal sticks or metal electrodes so that the tension produced an arch of intense white light crossing the gap between the electric poles (Bönt, 2009). More than forty years passed before arc lighting was used for general lighting (Schivelbusch, 1988, p. 54) After several technological obstacles had been overcome,[450] arc light was tested and displayed in public experiments like the one performed in Lyon by the engineers Lacassagne and Thiers in 1855.

[450]First, mechanical regulators had to be developed for keeping the positively and negatively charged electrodes at an equal distance while the 'electric candle' burnt down in the heat of its electrical discharge. Furthermore the

The new light created another public sensation. According to French newspaper reports, the new light was so strong that it woke up birds that began to sing and prompted ladies to open up their umbrellas 'to protect themselves from the rays of this mysterious new sun.' (in Schivelbusch 1988, p. 55).[451] In the 1870s arc lighting was fully operational. During the 1878 Universal Exhibition in Paris arc lamps lit the Place and Avenue de l'Opera and observers reported enthusiastically: 'The vista is about two thirds of a mile, and the effort incomparatively finer than any show of artificial illumination ever before seen.'[452] When the first US municipality Wabash in Indiana switched on their newly purchased arc lighting system a newspaper described the inauguration scene and public reaction:

'Suddenly from the towering dome of the Court House burst a flood of light which, under ordinary circumstances, would have caused a shout of rejoicing from the thousands who had been crowding and jostling each other in the deep darkness of the evening. No shout, however, or token of joy distributed the deep silence which suddenly settled upon the vast crowed. … The people, almost with bated breath, stood overwhelmed with awe, as if in the presence of the supernatural.'(in Jakle, 2001, p. 41).[453]

Next to arc lamps, gas lighting looked like an inefficient yellow glow. The harsh white arc light also excelled gas flames in steadiness but had to be hung up high, outside people's field of vision, in order to avoid glare.[454] It was, according to Schivelbusch, 'the most modern form of illumination of its day' but also 'a technological step backwards.' In contrast to gaslight, the incandescent electrodes burnt in an invariable intensity.

Yet in the long run, the 'dazzling' technology did not establish itself. The battery supplied arc lamps could neither be controlled individually nor from a central supply system. 'Like the

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batteries and electrode material had to be improved (Schivelbusch, 1988, p. 54). The European Jablochkoff's standard arc lamp[450] lasted for up to sixteen hours but was more difficult to service than gaslights (Jakle, 2001, p. 39; Jonnes, 2004).

451 'Unlike all earlier innovations in lighting which had been metaphorically compared to the sun, arc lighting really did resemble sunlight, as spectrum analysis shows. As bright as daylight, arc-light overwhelmed people when they experienced it for the first time.' (Schivelbusch, 1988, p. 54) The arc-light was, in fact, a small sun and the light it cast had a spectrum similar to that of daylight (ibid: 118).

452 Professor Silliman, in Preston S. Millar, 'Development of Street lighting equipment,' Electrical Review 76 (May 8, 1920):770. In Jakle (p.40, source 265).

453 Like many of his contemporaries the reporter pointed to the curious fact, that one could read a newspaper in the new light. An Image by Carl Saltzmann (1884) shows the first public arc lighting on Potsdamer Platz in Berlin where a man is reading his newspaper next to an advertising pillar. See: http://www.culturalsourcesofnewness.net/articles/berliner-nacht-im-museum/.

454 Arc light was therefore considered unsuited for domestic use. The burning incandescent electrodes produced not only lots of heat but were also and more importantly, too bright and harsh for private homes. Some contemporaries even felt the light was generally unsuitable for human needs as it was perceived as 'horrible, unearthly, obnoxious to the human eye; a lamp for a nightmare.' (quoted fromBrox, 2010, p. 105)

candle and the oil lamp, arc lighting was governed by the pre-industrial principle of a self-sufficient supply.' (1988, p. 56) In Europe, arc light was mostly used for lighting public squares and larger areas. It was also 'unsuitable for general-purpose street lighting' for its excessive light output and its 'prohibitive costs' (pp. 118-120).

In the United States, the situation was different. Brox argues that the key American arc light provider 'offered more light for less money—a double strangeness, to have intensity no longer tied to cost.' Yet Jakle also shows that 'the initial adoption of electric street lighting in the United States varied substantially from city to city, as a function of local politics, the felt need for the new technology (itself a function of already existing gas lighting), and the preferences of lighting enthusiasts.' (2001, p. 47) This is nicely illustrated by the heterogeneous use of arc lighting towers, clustered powerful arc lamps with up to 4,000 candles mounted in great heights.[455] Many U.S. cities tried these 'electric moons' that were meant to illuminate whole neighbourhoods. Some installed towers in downtown districts. Detroit erected an extensive installation of 175-feet-high towers with six 2,000-candlepower lamps each. The 'twilight' they shed on the city was uniform but shaded by buildings and trees and 'bore little if any relationship to traffic and other needs below.' (Jakle 2001, p. 50) Despite lower operation costs, Detroit soon dismantled its innovative lighting and reinstalled lanterns.[456] Jakle concludes with Schivelbusch that arc light overshot the mark and 'proved merely an exercise in technological monumentalism.'

The arc-lighting intermezzo nicely illustrates the complexity of public lighting. For the first time in lighting history, municipalities could choose between two technologies that both 'truly lit' urban spaces but in very different ways. The installation of few arc light towers could reduce maintenance efforts and costs but only at the expense of the control of light levels and light distribution. At a time when citizens were used to human-scale light points—and stunned by arc lamps—lighting engineers refined their instruments to measure light in space.

With their peculiar light distribution, the 'electric moons' thus offered not only an alternative energy source but also an alternative way of lighting cities. New developments in light engineering allowed experts to address this question of light quality scientifically. In the

[455] Schivelbusch also reports early 18th century ideas about public lighting as a centralized system of *city* lighting rather than a dispersed *street* lighting infrastructure. (1988: 120-21).

[456] 'Detroit sold its towers to Austin Texas, where they were re-erected and remain today, the last remnants of this early system.' (Nye, 2015). Footnote: 'Austin's sixteen towers, still in operation in 2010, are now a registered historic landmark. Mark Moore and Karl Strand "Preservation Study of the Moonlight Towers," Austin, Texas, APT Bulletin, Vol 23, No 1, 29-38.'(Ibid: 7).

1880s, the professional evaluation of urban lighting was transformed by the invention two new photometric measuring devices, the radial photometer and the illumination photometer. While the existing candle standard measured the light output of a lamp in only one direction, the radial photometer captured light emission all around, ‘at angles above and below the horizontal plane’(Otter, 2008, p. 186). The so-called illumination photometer or illuminometer, developed by the English lighting engineering pioneer Alexander Pelham Trotter, was designed to measure the distribution of light in space. ‘It is not concerned with lamps, but with what the lamps do’, emphasised Trotter. After all, the performance of a lamp in a laboratory space had little in common with its actual use in urban spaces, where facades, windows, sand or cobble stones reflected or absorbed their light. While the candlepower of a lamp was a value for describing its brightness, candle per foot or candle-foot was henceforward the unit for measuring the illuminance, that is the brightness shed on a given surface. In 1896, the international standard *lux* replaced the candle-foot (Otter, 2008, p. 170).[457] Otter suggests that arc lighting contributed to these photometrical advances as the light source made it obvious that the brightness of a lamp does not necessarily coincide with bright streets.

9.3.2 Light bulbs: A system solution, superior to gas and arc lighting

While the competition between gas infrastructures and gaslights went on, a third technology reached maturity and made the race. The success story of the incandescent light bulb illustrates in an exemplary way how the new replaces the old by first imitating and then surpassing it. In comparison to gas and arc light, the incandescent light bulb united the advantages of both existing technologies by offering bright, steady, odourless and efficient lighting. However, other than arc lights, which worked with batteries or generators, light bulbs were designed as part of still inexistent electrical power networks that were as complex, but cleaner than gas infrastructures.

Historians have described the invention of the electric light bulb, the emergence of electric power networks and its system builders from various perspectives and in great detail. By addressing key issues like network formation and valorisation of innovation, they add new aspects to the histories of urban lighting assembled in this chapter.

[457] Candlepower, as a measure for the luminous intensity of a light source, later became what is today known as *candela*, which became an international unit in 1948. Previously, German-speaking countries and Scandinavia used the Hefner lamp as a standard (Wikipedia.org; Hasenöhrl, forthcoming).

The new must be brought into the old so that we can recognise it, writes Helga Nowotny (2008). In the valorisation process of electric lighting as newness, gas and arc lights fulfilled the function of the old. From this point of view, Thomas A. Edison's achievements as an 'inventor-entrepreneur' can be described in terms of enhancing the contrast, comparability and, hence, the competition between existing and new lighting technologies. According to George Basalla, 'Edison was well aware of the limited usefulness of arc lights for interior illumination' and planned to develop a light source that could serve both private and public interests (1988, p. 47). Like gas lighting, it was designed as component of a larger integrated system including generators, power lines, switches, fuses, etc.

Edison's design vision had material effects. Without compelling technical reason, he chose to bury the power lines for his first New York public lighting project underground, although the digging was expensive and required extra legal permission and an improved isolation of the power cables.[458] Andrew Hargadon concludes:

> '[Edison] deliberately designed his electric lighting to be all but indistinguishable from the existing system, lessening rather than emphasizing the gaps between the old institutions and his new innovation. Closer examination of these design choices makes his decision to mimic gas seem more dependent on social than technical considerations.' […](Hargadon & Douglas, 2001, p. 489)

Accordingly, Bazerman highlights the valorisation aspect. Gaslight infrastructures were 'already accepted as a social fact' not only in a material sense but also as part of 'numerous meaning systems'. In the face of the various negative environmental side-effects of the coal and gas industry, which were publically known by the time, electric lighting appeared more appealing and hence more valuable. 'A beatable competitor', gas lighting thus helped 'advance the acceptance of Edison's novelty by making its reality seem more imaginable and by decreasing its disruptiveness.' (1999, pp. 144-145) At the same time, the disadvantages of arc lighting made its new electric alternative appear more appealing. Edison explicitly intended to imitate the mild light of gas rather than the blinding light of arc lamps. (Basalla, 1988, p. 48).

[458] Edison's feeling about power lines above ground in New York City might have been right. The arc lighting on Fifth Avenue, a prime residential street, 'was dismantled after *residents objected to the unsightly wires* connecting the fixtures.' (Jakle, 2001, pp. 45, my emphasis)

Thus, the combination of aesthetic appeal and familiarity facilitated the innovation process. The latter has been described as a process of network formation, which involves human and non-human entities (Akrich et al., 2002a; 2002b). On the one hand, innovators need to define and solve technical problems, on the other they need to raise public interest and find allies for their ideas. In this respect too, the just-described 'robust-design' of urban electric lighting networks (Hargadon & Douglas, 2001) was an effective strategy for enhancing public support.

'City and town dwellers had been well prepared to understand, accept, and pay for a centrally delivered lighting technology by their experience of gas lighting, supplemented by the newly emerging electric arch lighting industry.' (Bazerman, 1999, p. 148)

Another challenge was to assemble the technical artefacts in the form of a 'large technological system'. In this respect, the historian Thomas Hughes, whose influential analysis has also inspired sociological innovation research, points to the talent of 'system builders' like Edison to identify those technical problems, the so-called 'reverse salients', that hamper or hinder technological development. On the other hand, Hughes describes the emerging 'networks of power' as 'both cause and effect of social change' (1983, p. 2) stressing the crucial impact of 'technological momentum'.

> '… large-scale technology, such as electric light-and-power systems, incorporated not only technical and physical things, such as generators, transformers, and high-voltage transmission lines, but also utility companies, electrical manufacturers, and reinforcing institutions such as regulatory agencies and laws.' (Thomas P. Hughes, 1989, p. 460)

More than his competitors,[459] the inventor-entrepreneur Thomas A. Edison was successful in both respects. As a bricoleur and experimenter, he assembled the right team in the right place, his laboratory in Menlo Park, and had a talent for putting his finger on the crucial technical problems[460] (Akrich et al., 2002b; Thomas.P. Hughes, 1979; Miettinen, 2006). As an entrepreneur he possessed the communication skills for feeding and creating expectations and exploiting the 'technological momentum' of his time.

As Bazerman points out, Edison not only chose the right material design but also used the appropriate languages. He knew how to translate his visions so that they made sense and

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[459] Edison was neither the only one nor the first to work on and refine electric lighting solutions. His achievements were contested by other developers of incandescent light bulbs like …. (VDE Band).

[460] He experimented as long as it took to find the right material for the glowing filament inside the light bulb.

appealed to others. Edison knew how to get and orchestrate the attention of the mass media, which was so important with regard to creating a network of allies, including investors and public support.[461] But his translation skills were also reflected in his sense of timing. Long before the first public presentation light bulb, announcements in interviews and articles raised early attention for the project. Meanwhile, experimenting, research and development went on in Menlo Park, removed from the public eye. Accordingly, the crowds poured in when Edison invited the interested public to visit his laboratory at the end of 1879. For the event, the Menlo Park compounds were lit by incandescent light bulbs and Edison himself patiently explained his invention to his audiences (Bazerman, 1999).

The support of both financial backers and lay publics was crucial when facing the gas industry's interests and obdurate institutional structures. In the face of a disruptive change, New York gas utility stock holders were suspicious of the new system. Strong alliances between the gas industry, municipalities and political institutions slowed down the introduction of electric lighting systems. In 1878, the British Parliament commissioned a scientific committee to evaluate Edison's recently announced innovation plans. Like their peers in the US, the physicists and chemists came to the conclusion that the inventor had promised the impossible and demonstrated 'the most airy ignorance of the fundamental principles both of electricity and dynamics' (Conot, 1979, pp. 129-133; quoted inHargadon & Douglas, 2001, p. 486). Berlin's important electric industry, too, competed with the municipal gas utility for the provision of public lighting (Hasenöhrl, forthcoming; Thomas P. Hughes, 1983).[462]

Edison used different formats and locales for presenting the innovation to different lay and expert audiences. Bazerman describes in detail how Edison adjusted his public presentation strategies to the technical development of his electric lighting system. Trade exhibitions offered welcome occasions for directly comparing competing technical solutions. The first public electric lighting system was implemented in Pearl Street station in New York and opened in 1882 (Bazerman, 1999, pp. chapters 8-11).

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461 Edison thus managed to build a powerful social network of allies, including investors, heavy-weight business partners and the press. Up-front media reports on the promising innovation activity in New Jersey, USA secured a positive and highly expectant public climate for network building endeavours (Bazerman, 1999). Looking at LED lighting, history seems to repeat itself. Media reports promise a better, greener, healthier future.

462 For an account on forms of resistance against the electrification in US country side see Kline (2003).

Public expectations, the support of lay audiences and the growing demand for lit urban spaces was politically important. In this respect, historic accounts reveal the semiotic particularity of light technological innovation. Enthusiastically received and publically appealing as it was, light drove the much larger electrification process. The establishment of electrical power networks was promoted as a light technological innovation. 'Although Edison clearly had larger designs for the electrification […], the projected technology soon was narrowly represented as incandescent illumination.' (Bazerman, 1999, p. 148) The triumphant goddess, not with a flag or torch but with an electric light in her hand, was a popular promotional image of the electric industry (Binder, 1999).[463]

The appeal of the light bulb thus contributed to material changes in the urban design and facilitated a far-reaching disruptive technological transformation. At the end of the 19th century, electric energy became synonymous with economic progress and new 'modern' life styles. The electric light bulb, as one among other usages of electric energy, stood out as the most visible and shining symbol of electric technology (Binder, 1999).

The historian David Nye, too, highlights the semiotic power of the innovation. Taking a socio-cultural perspective he shows how spectacular light displays added to what he calls the 'electrical sublime' (1996). American cities and towns kept upgrading their public lighting 'as a signal of their growth and importance' until arc light towers 'fell out of favour' when the electric light bulb triumphed offering 'more dramatic lighting displays'.464

Nye's account thus offers strong evidence for the importance of the semiotic dimension of innovation and highlights the effects of public technological trials and displays in the innovation process. He shows how new tastes and demands for public lighting emerged as a result of sensational, aesthetic experiences in the course of events like urban public festivities, world fairs or fair grounds (David E. Nye, 1990). Extravagant and extraordinary illuminations stunned the audiences of the Paris World Exhibition in 1900, of public celebrations and in amusement parks (David E. Nye, 1990; Schivelbusch, 1992). Spectacular temporary light displays, so his thesis, 'became the basis for permanent night illuminations' (1996, p. xv).

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[463] See the AEG trade mark: http://www.gerdflaig.de/AEG_Geschichte/webFotos/1894SchutzmarkeAEG.jpg, last access 2014-05-03.

[464] Comparing arc lamp and incandescent light bulb, Nye argues that Americans rejected the first, in favour of a less natural and moon-like and '*more dramatic lighting displays that emphasized some features over others and gave greater prominence to commerce*.' (2015, pp. 7, my emphasis). From the light-technological view, this argument seems less plausible. However, from a sociological point of view and with regard to my research question the claim is highly interesting and raises important questions as to who were these 'Americans' and how did they articulate their preference for 'dramatic lighting'.

9.3.3 Road lighting: Lighting standards for car-oriented modern cities

The technological advancements can only partly explain the transformation of urban lighting practices. Schivelbusch argues that the brightness of light sources around 1900 hardly changed. There was no demand for brighter or different lights. Gaslight set the standard in terms of appropriate light levels and light colour. 'When developing the first light bulb, Edison himself had aimed at imitating the red-yellowish glow of gas light.'(1992, p. 27)

Yet there were other reasons to lighten up urban spaces in new and brighter ways. As in the case of the early-modern 'nocturalization' (9.1.2.) changing life-styles and the increased mobility and traffic in night-time urban spaces raised the demand for urban light planning. With the industrialisation, working hours had become decoupled from the day-and-night rhythm (Melbin, 1987). With the urbanisation, new forms of urban night life developed in industrialised cities, including Berlin and Lyon (J.-M. Deleuil, 1994; Nentwig et al., 2008).

Four driving factors outlined by Mark J. Bouman for the 19th century (1987) continued to shape urban lighting practice in the 20th century. '[T]he quickened tempo of night life, the development of central business and entertainment districts, the proclamation of public order, and competition with other towns' secured street lighting a 'lofty place' in the public perception of citizens.[465] 'After 1900, the passion surrounding the politics of electric lighting highlighted the degree to which illumination had achieved utility status in the popular imagination.'(Bouman, 1987, pp. 13-14).

In addition to the already existing impetus, a number of social, technical and political innovations created new demands and raised new issues. The faster the traffic on the streets, the greater was the need for better visibility and brighter lights. As motorised traffic increased, artificial lighting 'became primarily a facilitator of auto use after dark, as public streets were made fully into traffic arteries.' (Jakle, 2001, p. vii). Traffic safety became more important as public concerns about security issues and the surveillance of nocturnal urban spaces faded in the brighter light of the new gas and electric luminaires (Mosser, 2007, p. 79).

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[465] Expressed in more detail, that means that first, 'night-work and leisure continued to increase. […] Second, in industrial cities, status- and class-based segregation increased, particularly after the introduction of mass transit.' (p. 12) In this situation, light was associated not only with luxury but also with cleanliness, social order and even progress.[465] Accordingly and third, the illumination was considered an effective remedy against vice and crime in nocturnal urban spaces and certain districts (see also Otter, 2008). Finally, capitalism and urban competition was an impetus for street lighting. 'Streetlights, illuminating shops stuffed with products, could advertise that a city was a good place to buy and sell and in which to invest.' (ibid)

The changing patterns of usage coincided with advancements in lighting engineering as a professional field and a scientific discipline. Newly founded professional associations were responsible for the development and standardisation of measurement procedures and quality criteria that gained particular importance in road lighting (Mosser, 2008). The German society for lighting engineering (*Lichttechnische Gesellschaft, LiTG*) was founded in 2012 (Luxbacher et al., 2001), the French society AFE (*Association Française de l'Eclairage*) in 2013. The International Commission on Illumination (Commission International d'Éclairage) was established in 1913. To the present day, these professional institutions have set the technical standards and guidelines that build the basis for product development and public lighting applications, on the national and EU level (Liman, 2000).[466]

As already pointed out, standardisation activities and photometry evolved as light technological developments raised unprecedented physiological problems like glare. For instance, Hasenöhrl suggests that the relationship between safety and glare was 'probably the most institutionalized of all contested aspects related to outdoor lighting' (forthcoming). The brightness of electric lighting not only led to new lamp designs and modifications like reflectors and screens or new indirect lighting techniques (Binder, 1999; Schivelbusch, 1992). It also prompted lighting engineers to perform lighting experiments as an empirical basis for the above-mentioned quality standards.

Lighting engineering involved photometric laboratory research. With the advancement of the new scientific discipline, the gap between controlled laboratory conditions and the messy 'real' street conditions grew wider. Light technological tests further institutionalised the scientific laboratory and the public street as two distinct spaces for evidence production.[467] Public displays thus offered the manufacturing industry valuable information about the situated perception of new lighting fixtures and sources. For instance, the Berlin city administration allowed lighting companies to study the potentially harmful effects of glare on the human eye by allocating public spaces 'for practical testing' of their technical equipment.

[466] The West German non-binding road lighting standard DIN 5044 was introduced in 1955. In the GDR, a corresponding standard TGL 200-0617 was introduced in 1967. A European standard was established in 2005. It contains five parts, whereas the first remained national. The respective German version is thus DIN EN 13201, while the French standardisation body AFNOR issued the French pendant NF EN 13201. http://www2.afnor.org/espace_normalisation/structure.aspx?commid=2404

[467] This corresponds with social and cultural histories of science that describe the early-modern emergence and diversification of auditoria, stages and exhibition spaces for public and scientific demonstrations that did not exist before (Ophir & Shapin, 1991; Stafford, 1994).

‘This approach could result in a somewhat eclectic design of public spaces’ (Hasenöhrl, forthcoming).[468]

In addition to physiological aspects, guidelines also accounted for average traffic volumes and the built environment of the lighting fixtures. Sophie Mosser nicely outlines how recommendations for ‘good’ public lighting practice correspond to the urban planning paradigm of the car-oriented city and based on photometric perspectives on light users (2008). The researcher and engineer criticises the ‘exacerbated functionalist conception’ of public lighting that prevailed until the 1970s. Public lighting for motorised traffic privileges the quantitative evaluation of light levels and homogeneously lit road surfaces over qualitative criteria.[469] This perspective corresponds with more recent trends in urban planning and the contemporary critique of lighting designers who criticise the ‘sodiumisation’ of urban spaces, that is the uniformly yellowish street lighting with high- or low-pressure sodium lamps (Mosser & Devars, 2000, p. 23; Schulte-Römer, 2010, p. 25).[470]

Last but not least, the ‘sodiumisation’ of city centres is also a great example of how the car-oriented urban planning paradigm and the respective road-lighting standards have shaped technological development. The electric light bulb had been decisive for the technological transformation form gas to electricity. But the principle of arc lighting was not entirely dismissed and further developed in the course of the 20th century. Dazzling as they were, gas-discharge technologies—low and high pressure sodium vapour lamps, metal halide lamps, fluorescent light tubes and the now out-phasing mercury vapour lamps—offered the most efficient solutions for road lighting. One of these innovation stories has been told by Wiebe

[468] While laboratory testing and product standardisation has been refined, test streets are still implemented today. In terms of lighting engineering as an evidence-based science discipline, such tests raise questions about the relationship between the laboratory and the real world. After all, the standardisation of lighting products and practices implies generalizable physiological facts and standard urban situation. In other words, laboratory experiments produce scientific facts about the light sensitivity and reactivity of the human eye in a clearly defined and controlled setting or experimental framing. Reality, in contrast, can be much more complex in terms of individual experience and response and with regard to changing and interacting variables in urban situations. What could be considered as a common reaction and ‘normal’ physiological response could serve as a basis for ‘good’ public lighting practice.

[469] « Issu d’une logique originellement hygiéniste, sécuritaire et d’embellissement, l’éclairage public s’était enfermé, avec l’avènement de l’automobile, dans une conception fonctionnaliste routière exacerbée jusqu’aux années soixante-dix : adapté, en termes techniques, aux exigences du déplacement automobile, sa conception se basait alors uniquement sur le respect quantitatif de niveaux lumineux et d’uniformité. » (Mosser & Devars, 2000, p. 65)

[470] *« L’approche fonctionnelle est remise en question, permettant la construction d’un nouveau cadre de référence pour la lumière en ville. Les débats entre professionnels issus des métiers classiques comme les ingénieurs électriciens et les nouveaux experts font ressortir le besoin d’une lumière urbaine esthétique et pas seulement fonctionnelle. Les critiques sont alors axées sur l’uniformisation des paysages urbains nocturnes, sur ce que certains appellent la « sodiumisation » des villes, en référence au recours généralisé à l’éclairage par lampes à sodium.»* (Gonzalez, 2010, p. 25)

Bijker from a social constructivist perspective. Focusing on the invention of fluorescent lighting in the late 1930s, the sociologist demonstrates how U.S. manufacturers and electricity utilities designed the new light source not only with regard to technical possibilities and constraints but in line with their interests to sell lamps and electricity (W. Bijker, 1992). Jakle offers a comprehensive history of US street lighting and the development of new gas-discharge light sources that goes beyond the scope of this historic overview. What is important to note though is that electric light sources diversified in terms of technologies, product performance and light outputs and efficiency and in line with increasing and diverse demands for city lights. In public street lighting, gas-discharge technologies replaced electric light bulbs and still remaining gaslights in the second half of the 20th century.

9.3.4 Private lights: Architectural design and commercial illuminations

Lighting technologies and practices not only diversified due to car traffic. They were also further developed to meet the new arising demands in architecture and urban design. The just-mentioned profession of the lighting designer or light planner only emerged in the middle of the 20th century. Yet its roots can be traced back to the arts-and-craft and avant-garde movements of the early 20th century.

The transformed relation between social space and time greatly affected city planning and architecture as the 'masterly, correct and magnificent play of masses brought together in light.' (Le Corbusier, 1923). Early-20th century designers and architects rediscovered natural light as well as artificial lighting as a new material and means of aesthetic expression (Hirdina, 1997). Their work reflects not only the latest technological developments but also the above described socio-cultural transformations in labour, leisure, urban life-styles and mobility.

Artificial light was at the heart of new forms of artistic expression like photography and cinema.[471] New developments in stage design and architecture laid the basis for a new profession—lighting design. On the theatre stage, avant-garde artists like Adolphe Appia, Peter Behrens and Edward Gordon Craig created new spaces and atmospheres with stage lighting (Brauneck, 1982; Schivelbusch, 1992). So did architects like Bruno Taut, who presented a glass pavilion at the 1914 *Werkbundausstellung,* the exhibition of the German

[471] Home to the brothers Lumière, Lyon is famous as the home of the early film industry (LIT).

designers association, in Cologne (LIT). Martin Gropius designed the new Dessau *Bauhaus* building with a large glass front which offered little protection from the cold but made the building look like a shining cube when lit from within at night (LIT).[472] In 1930, his colleague László Moholy-Nagy presented the 'Light-Space-Modulator', a design experiment with the spatial effects of light and movement (Hoormann, 2003).[473] Modern works of steel and glass like Mies van der Rohe's glass cubes or his emblematic Seagram building in New York City questioned the separation between interior and outside space and led interior designers and architects to rethink artificial lighting and its effects (Neumann, 2010).[474] Thus, professional lighting design emerged as architects and stage designers began to specialise in lighting.[475]

However, there is another area of lighting practice compared to which the impact and effects of architectural lighting design appears marginal. The night-time image and experience of the 'modern city' was, above all, shaped by commercial illuminations, which became an epitome of progress, luxury and metropolitan life-styles (Binder, 1999; Hirdina, 1997). Shopping streets were the brightest and, like in Berlin and Lyon, first lit on the initiative of private retailers and shopkeepers. In 1928, Berlin's shopping boulevard Kurfürstendamm was lit in the course of the *Werbewoche*, a week-long celebration of the metropolis as a place of commerce, which went down in history under the title '*Berlin im Licht'* (Berlin illuminated) (Frecot & Sembach, 2002; Nentwig et al., 2008; Stock, 2008-06-22). A song by composer Kurt Weill dedicated to the occasion explicitly relates the Berlin city lights to modern urban night life. The German song text reads in English: 'Sun light is fine if you want to go for a stroll. But if you want to see the city, the sun is not enough.'[476] Apart from electric light bulbs,

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[472] http://www.bauhaus-dessau.de/english/home.html
[473] http://www.medienkunstnetz.de/werke/licht-raum-modulator/
[474] Scott McQuire remarks: 'In conjunction with the proliferation of transparent and highly reflective surfaces, the ability to illuminate the cityscape in new ways introduced an important new dimension into urban design, one that belonged to neither architecture nor sculpture as traditionally understood. What emerges in the modern city is a new environment increasingly characterized by the overlap of material and immaterial spatial regimes, as distance becomes subject to new exigencies and urban surfaces increasingly function as illuminated screens. This "mixed reality" is an inherently dynamic and unstable environment: If appearances can shift rapidly, so can meanings' (McQuire, 2005, p. 134).
[475] Concealed, indirect lighting was among the inventions that went hand in hand with new architectural styles, in this case art deco. Schivelbusch calls the changes that became necessary due to the great light output of the metallic-filmament incandescent lamp a paradigm shift. Light was directed to white surfaces and reflected back instead of being shielded and directed as it was before. The result was a soft and diffuse light. As Schivelbusch points out, 'this lighting was not invented by a single technician or architect. It was the result of many simultaneous reflections, experiments and constructions.' (Schivelbusch, 1992, pp. 35, my translation) Immediately, experts of the Illuminating Society discussed the downside of this new way of lighting architecture and spaces arguing that people felt lost, if they could not see the light source and that there was no point on which the eye could rest (Schivelbusch, 1992, p. 36).
[476] "Berlin im Licht"-Song: *"Und zum Spazierengehen genügt das Sonnenlicht. Doch um die Stadt zu sehen, genügt die Sonne nicht…*" (Schulte-Römer, 2013-02-19). The new look and feel of lit urban spaces was also a

neon signs became popular and emblematic for night-time city spaces (Ribbat, 2013). After the public-private street lighting, urban spaces and city images were now transformed and marked by privately installed and maintained shop signs and illuminated bill boards.

Although the private lights raised objections, most protests and attempts to regulate commercial illuminations were unsuccessful.[477] The war years, when strict regulations were imposed on private lighting practice and European fell dark, form an exception (Hasenöhrl, forthcoming; Hirdina & Augsburger, 2000; for blackouts in the USA seeDavid E. Nye, 2010).[478] Since then, light levels have continued to increase, light sources, equipment and applications have further diversified and so has the expertise of lighting professionals and experts.

The 20th century 'cacophony' of public and private city lights (Narboni, 2004) has prompted awe and wonder, has been the subject of controversies over the efficiency and quality of light, its physiological and environmental side-effects and its appropriateness (Hasenöhrl, 2015). They have reflected and reinforced the rhythm and specific urban atmospheres of the industrial, modern city (G. Böhme, 1995; T. Edensor, 2012), they have enhanced the semiotic potential of post-modern 'architectures of persuasion' (Venturi et al., 1977)[479] and enhanced the image and atmospheres in the 'post-industrial city' (Eckardt & Morgado, 2011).[480] Philosophers and cultural historians and aesthetics critics describe how temporal and spatial order have become relative and fluid (Virilio, 2000) with media and technologies

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popular subject in poems, literature and painting, for instance in Carl Saltzmann's reprentation of the Potsdamer Platz illuminated by arch-lights. http://www.culturalsourcesofnewness.net/wp-content/uploads/2013/02/Carl_Saltzmann_Erste_elektrische_Stra%C3%9Fenbeleuchtung-e1361291079991.jpg; last access 2013-09-22)

[477] 'Questions about the appropriate extent and style of illuminated advertisements were not only discussed controversially in the media, e.g., in letters to the editor. They also resulted in the formation of Expert Advisory Boards on the Beauty of Towns and Landscapes (*Schönheitskommissionen*) and in local regulations and ordinances for the protection of cityscapes.'

[478] In Germany, the inter-war and war-years were also special with regard to the National Socialist excessive light shows during political mass events, using military spotlights (Bartetzko, 1985). Albert Speer's electrically powered 'aesthetisation of politics' (Benjamin, [1936] 1979), commercial illuminations and architectural lighting by private actors have in common that they exploited and still exploit the semiotic potential of light to attract attention. With a special focus on iconic architecture, Georg Franck links the semiotic potential to capitalism calling it an 'economy of attention (1998).

[479] The seminal post-modern architectural manifest 'Learning from Las Vegas' (Venturi et al., 1977) questions the architectural criticism and modern style that was still prevalent in the 1970s and offers an appreciative reading of the popular 'vernacular' and iconic and commercial architecture and space design of Las Vegas. Rather than ignoring or 'denigrating' it, the authors describe the city as 'an architectural persuasion'. Its 'roadside eclecticism provokes bold impact in the vast and complex setting of a new landscape of big spaces, high speeds, and complex programs.' Without questioning the morality of commercial advertising and gambling they observe how 'styles and signs make connections among many elements, far apart and seen fast' (Venturi et al., 1977, pp. 8-9).

[480] For a more detailed explanation see my paper in the same volume (Schulte-Römer, 2011a).

‘underpinning the general shift from social “structures” to the “flows” of increasingly open systems’ (McQuire, 2008, p. 15). Geographers and sociologists point to the political problems of aestheticized politics and planning (T. Edensor, 2015; Hasse, 2006, 2007b) and show how the inequalities in the post-modern city are reflected in day- and night-time spatial arrangements and social practices.

10. Empirically relevant theoretical perspectives

Analytical lenses are useful for drawing our attention to aspects of empirical phenomena that are usually not problematised or considered separately and in detail. When looking at innovation, the boundaries between theory and innovation practice can get blurred as analytical concepts migrate or are designed to become management models or policies. In the case of LED lighting, two prominent conceptual assumptions about innovation processes stick out. The first is that LED lighting is a disruptive innovation, the second concerns demand-side innovation policies. As I will explain, none of these perspectives helps me answer my research question.

Disruptive innovation

LED technology is often referred to as a disruptive innovation or disruptive business (NSR, 2012-09; Thomond et al., 2003, p. 2). The notion of 'disruptive innovation'[481] was coined by Clayton M. Christensen at Harvard Business School in his book 'the innovator's dilemma' (1997).482 The dilemma is a tricky management problem, which can be described as follows: In the case of SSL, managers of incumbent lamp and lighting firms had to decide whether they invested in sustaining innovations, that is, improvements within the existing 'technological paradigm' (Dosi, 1982) of high-intensity gas discharge lamp technology, or if they invested in R&D in the field of electroluminescent SSL technology. While the first met existing demands and high expectations of mainstream customers, the light output and quality of LED lighting was long not suited for general lighting. The technology was first sold in niche markets and used for display backlighting, in traffic signals, and in decorative and architectural lighting (Zukauskas et al., 2002), which reflects the first problem with disruptive innovations: They first only appeal to 'markets and customers that seem insignificant or do not yet exist' (Bower & Christensen, 1995, p. 44). The second problem, the dilemma, lies in the fact that disruptive innovations develop rapidly, finally meet the criteria of the mainstream market and outperform incumbent technologies. A disruptive innovation like LED lighting

[481] 'Disruptive technology' is often used synonymously with 'disruptive innovation.' Meanwhile, the notion of disruptive innovation is preferred as it highlights the fact the disruptive technologies alone will not change a market. As the LED example shows too, new business models are needed in addition to technological invention in order to valorise the latter (Danneels, 2004).

[482] Christensen's book 'The Innovator's Dilemma' was taken up quite broadly in research and the media and 'received extensive coverage in business publications' (Danneels, 2004, p. 246). Its popularity reflects the performative potential of the approach to shape actual innovation activities and management.

redefines existing performance trajectories.[483] It 'changes the bases of competition by changing the performance metrics along which firms compete.' (Danneels, 2004, p. 249).[484] Eventually, incumbent firms will be overtaken by new market entrants. In the case of LED lighting, the latter often produce in Asia and have an expertise in electronics.

The disruption model quite adequately describes the turmoil on the supply-side, it is less suited as a framework for studying innovation outside firms. Technology users occur in the model as mainstream customers with conservative demands.[485] They are at the origin of the innovators' dilemma: Great firms fail because good managers make rational but bad choices. In order to satisfy their mainstream customers' demands they opt for sustaining technological developments rather than risky, potentially disruptive ones (Bower & Christensen, 1995, p. 44). Therefore, mainstream customers or marketing departments who know their clients perfectly well 'are the wrong people to ask' when it comes to risky management decisions (Bower & Christensen, 1995, p. 50).The right people to ask might be 'technical personnel with outstanding track records'(Bower & Christensen, 1995, p. 49)[486] and in some cases 'early users': When the first Apple computer was launched,…

> …'Apple had not placed a huge bet on the product and had gotten at least something into the hands of early users quickly. The company learned a lot from the Apple I about the new technology and about what customers wanted and did not want. Just as important a group of customers learned about what they did and did not want from personal computers' (Bower & Christensen, 1995, pp. 51, my emphasis).

Despite this hint at mutual learning and the co-evolution of innovation and demand, the disruption model is of limited use for my research. Although the framing of technology users as mainstream customers corresponds with the reality of most municipal public lighting

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[483] The distinction builds on Giovanni Dosi's model of technological paradigm shifts (Dosi, 1982). Such ground-breaking discoveries are followed by incremental innovations which then shape technological trajectories.

[484] A more refined definition has been suggested by Govindarajan and Kopalle and also favoured by Christensen. They consider a disruptive innovations as one that 'introduces a different set of features, performance, and price attributes relative to the existing product, an unattractive combination for mainstream customers at the time of product introduction because of inferior performance on the attributes these customers value and/or a high price—although a different customer segment may value the new attributes." (Govindarajan & Kopalle, 2006, p. 15).

[485] In a Schumpeterian tradition, mainstream customers are considered to have rather persistent tastes that will change only slowly over time (Schumpeter, 2006, p. 80).

[486] If the former defend a new technology 'even in the face of opposition from key customer and marketing and financial staff' management should be alarmed and warned. The authors thus conclude that 'the popular slogan, "Stay close to your customers" (which is supported by the research of von Hippel, 1988, and others), appears not always to be robust advice. One instead might expect customers to lead their suppliers toward sustaining innovations, and to provide no leadership-or even to explicitly mislead-in instances of disruptive technology change.' (Clayton M Christensen & Bower, 1996, p. 211)

services, the model cannot capture the plurality of public and private, expert and lay observers of the LED innovation. This is also due to the fact that the disruption model draws attention to a much earlier moment in the process of technological development, namely the moment when firms are confronted with a new technological paradigm and have to choose. Meanwhile, LED technology has already entered a phase of sustaining innovation activities. Innovating in public will not shape upstream disruptive technological change but might affect the trajectory of outdoor LED lighting. I conclude that conceptualising LED lighting as a disruptive technological innovation draws attention to the recognition and valorisation of new technology on the supply-side rather than the public situations of testing and showing and heterogeneous sets of actors on the demand-side.

Demand-side policies and innovative public procurement

Another perspective on LED lighting, that is widely shared among innovators, is closely linked to the diagnosis of market failure: 'There was no market for LED street lighting' (NSR, 2010-07; municipal consultant, 2012-02-03). In such cases, a policy-oriented innovation literature recommends governments to take demand-side innovation measures. Until the 1990s, such 'interventionist' policies did not match with the EU's regulatory goal of creating a 'free' single European market (Edquist et al., 2000, pp. 7-8). However, the political climate has changed in the EU as well as in other OECD countries, and governments have expanded their political involvement beyond R&D funding and supply-side policies. 'This interest in demand-side innovation policy has emerged as part of a greater awareness of the importance of feed-back linkages between supply and demand in the innovation process' (OECD, 2011, p. 9). It is further argued in the OECD report that 'demand-side innovation policies are part of an evolution from a linear model of innovation, usually focused on R&D, to a more broad-based approach that considers the full scope of the innovation cycle' (ibid, p. 9). But who plays a role in this cycle and what is fed back?

An important aim of demand-side policies is the creation of 'lead markets' (Edquist & Hommen, 1999). 'Successful innovations in lead markets are considered to have a higher potential for becoming adopted world-wide than other designs being developed elsewhere' (Uyarra & Flanagan, 2010, p. 132). In this respect, innovative public technology procurement is highlighted as an effective policy instrument (Edler et al., 2005; Edquist et al., 2000; Edquist & Zabala-Iturriagagoitia, 2012). It is considered as a remedy against market and system failures caused by uncertainties and asymmetric user-producer relationships and uncertainties (Edler & Georghiou, 2007, p. 955; cf. B.-Å. Lundvall, 1985). Innovative public procurement also implies early technology implementations which are supposed to function as showcases that can enhance the innovators' credibility and demonstrate the maturity of an innovation.

As a policy device, innovative public procurement is recommended for initiating, escalating or consolidating markets, depending on the innovation stage in which procurement takes place (Edler et al., 2005). It is also suggested that it can 'improve public policy and services' if it is linked to and combined with normative policy goals 'such as sustainability and energy efficiency' (Edler & Georghiou, 2007, p. 957).[487] It is further suggested that public procurers can play the role of demanding 'lead users' (cf. E. A. von Hippel, 1986) and introduce new societal values which justify the higher cost of innovation.

In theory, the demand-side perspective features innovative public procurers as active contributors to innovation. Their demand not only helps industries to promote their novelties but also to improve their products on the basis of user experiences and feedback. In practice however, procurement situations can be more complex and less ideal for innovation. As Robert Dalpé points out economic and political rationales do not always match. 'Elected officials attempt to maximize electoral support through procurement decisions' (Dalpé, 1994, p. 73). Innovative public procurement might be hampered because elected officials fear the electoral cost of failure or because 'science and technology decisions do not receive much public attention.' On the other hand, so Dalpé, procurement decisions are compared to other science and technology decisions 'probably the most publicized' (1994, p. 73).

The political interest in public visibility can also lead to a preference for projects that are prestigious or produce results before the next election.[488] The public visibility of innovative technological procurement is therefore ambivalent (Edquist et al., 2000, pp. 13-14). On the one hand, it can signal innovation, especially when it is financed by tax money and observable in public as in the case of public LED lighting (cf. Magill & Rogers, 1981). On the other hand, the symbolic appeal of innovation can prompt political decisions that lead to suboptimal socio-technical solutions. With regard to the valorisation of LED lighting, these observations suggests that there can be politicised situations in which LED lighting is considered as better per se just because it is an innovation.

Furthermore, the competence of public procurers can have an effect on what is installed to be tested or demonstrated in public. Veiko Lember and colleagues point out that innovative public procurement can be hampered by a 'shortage of proper know-how among procurement professionals regarding suitable procurement methods for fulfilling wider social goals'

[487] The proposed benefits of innovative public procurement are not limited to technological development but also include more general positive macro-economic effect. The respective literature gives a number of economic and political reasons why public procurers should invest in innovation despite the higher risk and cost. Most prominent are increases in overall demand that can foster economies of scale and competitive advantage for domestic industries. It is also suggested that the implementation of innovations can raise the technological standard of the location (Edquist et al., 2000, p. 8).

[488] Localised demand-side innovation measures can also lead to an unequal distribution of positive and negative effects within political administrative areas. In the case political procurement decisions tend to be taken in line with the interests of core voters (Dalpé, 1994, pp. 73-74).

(Lember et al., 2011, p. 1380). Public procurement is highly regulated on the international, EU and national level. Recent changes in the European legal framework, which would allow and encourage not only cheap but also ‘innovative’ or ‘greener’ public procurements, are not yet well translated into national and municipal directives and practices.

Competence is also crucial when it comes to specifying demands in the tendering process. Public procurers should be in the position to precisely define their needs. Dalpé argues that ‘requirements should be set by users and not by central agencies’ and that the procurers’ expertise to specify user-specific needs cannot be compensated by standards (Dalpé, 1994, p. 70). This statement challenges the claim that standardisation supports on demand-side innovation (Blind, 2008) and seems prerequisite for another claim namely the idea that ‘decentralized procurement that can allow better adaptation, and the ability to exploit local innovations for which there may not be information at the centre (Uyarra & Flanagan, 2010, p. 138).

Coming back to my research question, we can conclude that the literature on demand-side innovation offers important insights that allow us to better understand the wider institutional arrangements or innovation systems[489], in which the LED revolution takes place. It draws attention to legal constraints for public procurement and is itself an expression, or the reflexive basis, of current national and EU policies. As already mentioned, both European Commission and national governments within the EU encourage cities to deploy LED lighting and have set up funding schemes for accelerate its diffusion and supporting the creation of a European lead market for SSL. These measures lead to an increased number of LED implementation projects and showcases. They are also accompanied by extensive project monitoring and reporting. Feedback and information is produced and disseminated in the form of best practice reports, project evaluations or in presentations during conferences and meetings.

All these activities are part of the urban situations which I am interested in. However, the valorisations they produce tend to be generalised. This is not surprising as the focus of

[489] ‘Systems of innovation’ (SI) are institutional arrangements that are supposed to facilitate learning, knowledge production and information flows. They allow for loops and ‘complex interdependencies and possibilities for multiple kinds of interactions’ (Edquist & Hommen, 1999, p. 64). The notion of ‘national systems of innovation’ is deeply rooted in European innovation policies for ‘learning economies’ (B.-A. Lundvall, 1992). The notion of innovation *systems* highlights the structural aspects of innovation activities as opposed to innovation *processes* (Braun-Thürmann, 2005). For an overview of key characteristics of systems of innovation (SI) approaches see Edquist (1999). For an overview on differences in the ‘triple helix’ arrangements of industrial, academic and governmental institutions, also in the historical perspective, see Etzkowitz and Leydesdorff (2000).

demand-side innovation policies and also research is clearly macro-economic: ‘Public procurement for innovation represents one of the tools modern cities can employ to raise the level of competitiveness’ (Lember et al., 2011, p. 1390).

However, innovativeness, competitiveness and political visibility are not all that matters in urban situations. As Bengt-Åke Lundvall critically remarks[490], the ‘demand school does not distinguish demand, as a quantitative category, from user needs, as a qualitative category.’(1985, p. 28). The pro-innovation bias of this literature thus makes it difficult to see the outcomes of public testing and showing that do not relate to the imperative of ubiquitous innovating, market creation objectives and economies of scale. Instead, it reproduces the narrow economic and technology-oriented notion of innovation which I am trying to overcome in this work.

[490] Like the economist Eric von Hippel, who wants to overcome the ‘manufacturer-as-innovator bias’ (1988), Lundvall (1985) *stresses* the importance of vertical relationships between users and producers for learning economies and efficient innovation systems.

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