Sensory Governance

Managing the Public Sense of Light and Water

Nona Schulte-Römer

1. INVISIBLE INFRASTRUCTURES AND SENSIBLE ISSUES

Living in a German city, my everyday life is supported and stabilized by sociotechnical systems. Just now, I have switched on a light because it is getting dark, while in front of my window a line of streetlights has switched on to illuminate the street. This morning as every morning, I went to the kitchen and poured myself a glass of tap water and drank it—without worrying about the water quality. If I had not been writing this essay, I probably would not have even appreciated that I have drinking water running into my kitchen sink, electricity supply built into my walls, and a city-wide lighting system out there that illuminates my street via radio ripple control. I have grown up like this, I am used to this. I take public lighting for granted and trust that public water services provide clean drinking water, also known as the "best-controlled product" in Germany (UBA, 2015, December 2). I also had little reason to mistrust these public services. The streets are well-illuminated and the tap water is looking clean, odorless and tastes fine.

My attitude towards tap water and electric lighting can be best described as what cognitive scientists have termed "inattentional blindness" (cf. Zerubavel, 2015). I am not alone. In fact, the wide-spread blindness towards water supply systems and electrical lighting partly explains why they are often described as "invisible infrastructures" (Larkin, 2013) that have "sunk into the background" (Star & Ruhleder, 1996). Such infrastructures are extremely convenient to live with as long as they are properly maintained and work.

However, the invisibility of public infrastructures can also be problematic, if not paradoxical, for three reasons. First, the creation of sociotechnical expert systems and successful delegation of these basic services leaves us dependent and helpless in the event of sociotechnical failure. When the lights go out, as famously described by historian David Nye (2010), we can only hope that they will come back again soon and meanwhile experience the blackout as a state of exception. If water supply systems fail, people are forced to find alternative water supplies and eventually develop their

own, often informal infrastructures, which undermines the very concept of modern public services (cf. Gandy, 2014). Second, the "practical invisibility" (Jensen & Morita, 2015) of sociotechnical systems and services can prevent public discourse and democratic deliberation about infrastructural issues (Marres, 2007). As long as experts operate and maintain public infrastructures in exchange for tax payments and yearly servicing fees, we rarely care or ask questions. We might not even know that local and national governments outsource the management and planning of critical infrastructures to private companies (Collier, Mizes, & Von Schnitzler, 2016). Thus, inattentional blindness includes not only the 'invisible' technical infrastructures but also the actual maintenance work and care that keep these systems up and running (Graham & Thrift, 2007; Ureta, 2014). This public ignorance is often convenient, as it leaves experts a free hand. However, it turns into a problem when service providers seek user feedback and participation as they increasingly do in the course of complex sociotechnical transitions towards sustainability (Bogner, 2012; Chilvers & Kearnes, 2015; Dantec & DiSalvo, 2013). Third and finally, a lack of participation can also backfire in uncontrolled ways. Invisible infrastructures and services can resurface and cause undesirable political conflicts and slow down or even prevent sociotechnical projects—either because they fail or because they are transformed or replaced in the course of sociotechnical transitions (Baringhorst, Marres, Shove, & Wulf, 2019; Pohl, Hübner, & Mohs, 2012).

Indeed, current examples of resurfacing infrastructures show that the issues that "spark publics into being" (Marres, 2007) are often *sensitive* in the full sense of the word. In the case of the sustainability-oriented transformation from fossil to renewable energy sources, people protest against blinking wind turbines, the rotating shadows of their blades and infrasound (Pohl et al., 2012). To assume that these sensitivities grow on purely rational grounds, for instance falling property prices, misses the point. Instead, it seems that people develop rational arguments to justify or back-up their subjective sensory sensitivities, for which they have no direct scientific proof or logical explanations. For instance, while local residents might complain about the depreciation of their property when new infrastructures are built in their immediate neighborhood, the falling property prices are also an indicator for a noticeable depreciation of the sensory qualities of a place—in the form of noise, the loss of a cherished, 'unspoilt' or 'natural' view, atmosphere or an "age-old landscape" (Lintz & Leibenath, 2020). To publicly describe or account for this sensory loss is all but easy and often results in objectified techno-scientific responses rather than subjective narratives (cf. Bruner, 1986).

In this chapter I set out to explore how planners and providers of sociotechnical systems respond to and mitigate tangible, but also highly subjective and therefore elusive sensory sensitivities during sociotechnical projects. I further show how they are sometimes challenged by the users of their services. The notion I propose to capture these phenomena is 'sensory governance.' The concept evolved during my

ethnographic research on urban infrastructures in the lighting and water sector. Since 2009, I have studied the transition towards sustainable LED street lighting with a focus on Lyon, France and Berlin, Germany. In this period, I witnessed numerous sociotechnical tests and performances. I conducted interviews with lighting experts, primarily in Europe, and visited countless light-related conferences, festivals, LED installation sites and lighting trade fairs (Schulte-Römer 2015). While my own senses were sharpened through my participant observations, I found that most residents of newly LED-illuminated streets entirely overlooked this latest, radical light-technological innovation. This stood in stark contrast to the expert world of lighting, where LED lighting was the dominant topic and focal issue at the time. Looking closer at the paradoxical invisibility of innovative LED light, I realized that in some places, citizens were all but ignorant (see 2.1.). I also found that public attention or ignorance for public infrastructures was no coincidence—but rather closely related to how experts planned, installed, and maintained their lighting system. These insights can be transferred to other public infrastructures (see 2.2. and 2.3.). Around 2016, I observed similar dynamics when I began to conduct research on aquatic chemical pollution, attended expert workshops and visited central and decentral water treatment sites as part of a research project on aquatic micropollutants in German public discourse (Schulte-Römer & Söding 2019). Exploring the phenomenon further the German energy transition proved as another and particularly salient field to study 'sensory governance' (Schulte-Römer, Bleicher, & Groß, 2017).

Theoretically, the focus on practices that govern our sensory experiences and responses to sociotechnical matters taps into and can build on different bodies of literature, including cultural sociology (Lash, 2018; Reckwitz, 2017), human and historical geography (Edensor, 2017; Gandy, 2014), anthropology (Larkin, 2013) and science and technology studies (Bowker & Star, 1999; Hennion, 2004; Michael, 2020) as outlined in this chapter.

In the remainder of this chapter, I will continue with some illustrative examples of sensory engagements with public lighting and water systems (2). Please note, that these examples are not designed to offer robust scientific evidence, but only prepare the ground for my argument: Conflicts over sensory sociotechnical sensitivities regarding infrastructures are no coincidence, rather such conflicts are side effects of what I describe as the 'sensory governance' of sociotechnical infrastructures (3). Sensory governance thereby refers to expert strategies and procedures that are designed to make public infrastructures as unobtrusive as possible, up to the point where they get literally removed from the public eye. These expert ways of governing sensory experiences range from scientific thresholds for sensory nuisances to artistic designs aimed at beautifying sociotechnical infrastructures. I will conclude (4) that these practices, along with the sensory dimension of sociotechnical relations, have not yet been sufficiently addressed in transition research although they directly affect

sociotechnical transition processes in a twofold way. On the one hand, they ensure that sociotechnical systems remain what they should be: *Infra*-structures—the Latin for 'below'—that operate unobtrusively and below our attention threshold. On the other hand, objectified sensory governance always leaves space for subjective experiences. This is why infrastructures resurface and cause controversies that are difficult to settle. To deal with infrastructural sensitivities, so my claim, is a governance challenge that has so far received little attention in social-scientific transition research and deserves more reflexive approaches.

2. SENSITIVITIES AROUND LIGHT AND WATER

"The original field of aesthetics is not art but reality," writes political philosopher Susan Buck-Morss (1992, p. 6). "It is a form of cognition, achieved through taste, touch, hearing, smell-the whole corporeal sensorium." Anthropologist Brian Larkin takes up this definition to highlight the "sensorial and political experiences" evoked by infrastructures. "Aesthetics in this sense is not a representation but an embodied experience governed by the ways infrastructures produce the ambient conditions of everyday life: our sense of temperature, speed, florescence, and the ideas we have associated with these conditions." (2013, pp. 336–337). To stress that our encounters with infrastructures are often pre-reflexive, I refer to sensory experiences rather than aesthetic ones, which I consider as a way of knowing.

Public lighting and water infrastructures have ambiguous sensory qualities. The services they provide are highly sensorial, even aesthetic. Illuminations including streetlights shape the appeal and atmosphere of public spaces after dark (Isenstadt, Petty, & Neumann, 2015). The quality of tap water is evaluated based on its clean and pure look, taste and odor (Doria, 2010). At the same time, large parts of the sociotechnical water and lighting systems are hidden to the public eye. Water pipes and electricity lines are buried under ground and water treatment and power plants usually situated in the periphery and hence removed from sight and smell. Nevertheless, there are moments when these invisibilized infrastructures resurface—not only in the metaphorical, but also in a quite tangible, sensory sense. The following example show how system builders not only install and maintain urban infrastructures but thereby also create specific aesthetic experiences. They also show that this sensory governance sometimes fails to meet the taste of their clients and can be contested.

2.1 Keeping lighting invisible

In the past ten years, I have observed and studied the "LED revolution in lighting" (Schulte-Römer, 2015; Schulte-Römer, Meier, Söding, & Dannemann, 2019) and en-

countered a quite puzzling situation: From 2010 onwards, numerous municipalities have installed innovative LED lighting systems in public streets. Many were eager to hear citizens' opinions about the infrastructural redesign. Yet, unless the transition was accompanied by explicit projects for stakeholder engagement, feedback was non-existent or biased: In most places, residents of LED-lit streets remained silent and appeared indifferent about the technological transition in public lighting. But in some places, LEDs caused a public outcry and citizens publicly complained about or even protested against the new lights. These indifferent and negative responses to local LED projects stand in stark contrast to the worldwide enthusiasm for the innovation. Lighting experts and mass media highlight the unprecedented energy efficiency of LED lighting. In 2014, the Royal Swedish Academy of Science (2014, October 7) awarded the three pioneering LED inventors with a Nobel Prize in Physics for the invention of a new energy-saving and environmental-friendly light source.

The biased public responses are closely related to sensory issues, such as brightness levels, glare, or the color of LED light. Controversies over urban public lighting can be found worldwide from Montreal to Mumbai (Meier, 2018). In both cities, brand-new LED street lights were eventually replaced after public protest. The Indian case can serve as an illustrative example on how sensory aspects of lighting can turn into sensitive public issues. In 2018, my colleagues and I had the chance to interview the head manager of the Indian public-private company EESL (Energy Efficiency Services Limited) (Schulte-Römer, Dannemann, & Meier, 2018). At the time, EESL was carrying out a nation-wide infrastructural program, in the course of which all street lighting infrastructure was to be replaced with LED fixtures in order to considerably reduce the energy consumption for public lighting. As the head manager told us, the planning included not only the calculation of energy savings, but also sensory considerations. In particular, the engineers discussed the question of color temperature with manufacturers. They even did some pilot projects "just to get a feedback." As the head manager told us, "everybody agreed" that 5,700 Kelvin LEDs looked good. This feedback was good news, as cool-white LEDs also consume less energy than LED lights with a warmer color temperature.

Backed by the reassuring feedback, EESL continued their refurbishment work. Everything went well until in January 2015 they replaced the yellow lights that illuminated an iconic boulevard, the Marine Drive in Mumbai, with cool-white LEDs (see Figure 1). To the project managers' surprise, the light color change incited a public outcry and turned into an outright political controversy. Citizens claimed that the new light destroyed the atmosphere of the iconic place and made it look like any newly constructed neighborhood. They also found that the former yellow sodium lights had illuminated the wide pedestrian walkway next to the road and along the water much better than the newly installed LEDs.

Six months after the refurbishment the issue had still not been settled. Eventually, the Bombay High Court recommended that the municipality should change the lights on Mumbai's Marine Drive back to yellow in order to preserve the iconic look and atmosphere of the coastal road and boulevard. News channel NDTV India quoted the Chief Justice suggesting to the municipality that "The Queen's necklace is the pride of Mumbai. Why don't you bring back the sodium vapour lamps?" (Aora, 2015, July 7). The channel further reports that the replacement of the earlier yellow bulbs with LEDs had become "a political flashpoint" between the ruling Indian People's Party Bharatiya Janata Party (BJP) and its alliance partner Shiv Sena, a right-wing Marathi regional party. "While the BJP insisted that the white lamps were energy efficient and would bring down electricity bills by half, the Sena argued that they have stripped the city of its old-world charm." A leading Sena politician, Aaditya Thackeray, stated on Twitter: "Marine Drive is known as the Queen's Necklace. I'm not against LEDs, but that identity known to Mumbaikars and tourists must remain forever."

The conflict nicely illustrates how the resurfacing of an infrastructure can raise contradictory claims to the common good (cf. Boltanski & Thévenot, 2006). While EESL justified their choices on the basis of rational cost considerations, the local politicians highlighted the aesthetic appeal and cultural value of a public spaces. Eventually, the contradiction of efficiency-oriented innovation and heritage-oriented preservation could be mediated thanks to the flexibility of LED technology. As an Indian energy scientist and engineer explained in an interview with the Indian Express "white warm light will be better for Marine Drive… We can switch to warm white LEDs to retain the glow and use diffusers to reduce glare and make the streetlights more omnidirectional. Specialized lens design and adjustable mounting can help address the problem of light not reaching the footpaths, solving all the problems at Marine Drive." (Lukose, 2015). As EESL head manager told us (Schulte-Römer et al., 2018, pp. 100–102), "after a year of hearings, the court decided that the warm white won and we were asked to change the colors of the 6500 lights that we had installed on Marine Drive to warm white." So, they replaced the cool-white LEDs (5,700 Kelvin) with warmer ones (3,000 Kelvin)—not only on the iconic coastal boulevard in Mumbai, but also in religious places where people pray and also objected to the bright and cool-white new LED lighting. In a modern planned city in the North of India, the city government asked EESL to install LEDs with a color temperature of 4,000 Kelvin and so they did. Meanwhile, 90 to 95 percent of the refurbished public streets and squares in India are illuminated by cool-white LED lighting.

The Mumbai example is not the only case where lighting engineers responded to local aesthetic preferences. In Berlin too, citizens protested against the refurbishment of outdated gaslights arguing that their dim warm light Berlin's nighttime streets a unique and historic atmosphere. After fierce public protest, Berlin Senate

came up with a LED lighting scheme that mimicked traditional gaslights in design and light color (Schulte-Römer, 2015). In both cases, the new LED light threatened or disrupted citizens' sensory attachments with the familiar look and feel of a particular public space. In both cases, protest groups justified their personal discontent by enacting the cultural or historic value of the lost aesthetic quality. While the Mumbaikars highlighted the iconic value of "the Queen's Necklace," the gaslight friends in the German capital argued that Berlin possessed the worlds' largest gaslight heritage site. Doing so, these citizen initiatives reminded their public services that black-boxed infrastructures still have culturally meaningful sensory qualities that are not considered by technical standards for visual comfort and efficient road lighting.

Figure 1: "Yellow or white?" NDTV reports on and visualizes the controversy over the illumination of Mumbai's iconic boulevard.

Source: Aora, 2015, July 7

The conflicts that occurred in the course of LED refurbishments also confirm the findings and lessons learned from other sociotechnical transitions. Infrastructures resurface when the running system is changed. However, looking at the Indian LED transition, we see that the refurbishments only caused controversies where they challenged a site-specific and tacit, but nevertheless collective sense of comfort and convenience (Bille, 2019; Shove, 2003). Moreover, it seems that public controversies are more likely where infrastructures had already been publicly visible before a sociotechnical transition. This became particularly obvious when I studied the intro-

duction of LED lighting in Lyon, France and Berlin, Germany (Schulte-Römer, 2015). In the German capital, technical failure, privatization, and budgetary constraints had, since the 1990s, created a situation where citizens and tourists could not help noticing the relative darkness and broken street lanterns in the streets of Berlin. In Lyon in contrast, the municipal lighting department had enough resources to plan lighting strategically, carefully test the acceptance of new designs and technologies in small-scale experiments (Deleuil, 2009) or peripheral streets (Schulte-Römer, 2015). Moreover, the annual Lyon festival of lights has become the focal point of public, even worldwide attention while mundane public lighting practices remained in the background (Djaoui & Poirieux, 2007). I consider the Lyon lighting planners' care for their public infrastructures as sensory governance since their strategies and practices had the effect of drawing public attention to the lighting festival while the well-maintained street lighting sunk into the background and remained an invisible infrastructure and service. Ironically, the Lyon engineers were not always happy with their success at invisibilizing and seemed sometimes a bit disappointed that the citizens of Lyon showed so little interested in their faultlessly running, black-boxed lighting service.

2.2 Bringing sewage to the surface

Looking at urban water systems, the focus on the dis/engaging potentials of sensory and affective properties of water infrastructures has gained importance as "changes in the social role of science, complexity and uncertainty, contributed to the emergence of the general public as an important actor in water management" (Doria, 2010, p. 1). There are also several examples of resilience- and sustainability-oriented transition processes where the engagement and participation of water users as citizens was and still is a critical success factor (Ferguson, Brown, Frantzeskaki, de Haan, & Deletic, 2013; Sharp, 2017).

Sensory aspects are particularly obvious when looking at drinking water, which we instinctively check for murkiness or foul smell, and wastewater, which smells repulsive even from a distance. Accordingly, drinking water is associated with positive sensory qualities like freshness and pure flavorlessness. In contrast, wastewater treatment is associated with disgusting features. Coming close to wastewater treatment plants, we cannot help but realizing the bad smell of sewage and sludge, which is officially acknowledged as a "secondary environmental pollution" and "serious nuisance" (Frechen, 1988). Such odor emissions are not just a warning sign that is associated with health risks through foul water. Odor can also cause psychological stress and negative health effects like headaches, nausea, headaches and respiratory problems (Lebrero, Bouchy, Stuetz, & Muñoz, 2011). German regulation tackles this problem with thresholds for odor nuisance. To avoid it, wastewater treatment plants are not built in the midst of residential areas, but are situated in the periphery of

communities. However, the assessment of smell as an environmental pollution is all but straight forward. As an environmental expert told me, he relies on a pool of test persons, which he called 'normal noses' as their sense of smell can be described as average—based on European standards. Obviously, such assessments cannot prevent that individual residents who live in the vicinity of water treatment plants have a finer smell and feel disturbed, especially if the wind blows from the wrong direction. Nevertheless, the peripheral placement of wastewater treatment sites has contributed to a situation where the effluents of our modern lifestyle tend to be hidden in plain sight and socially irrelevant (cf. Zerubavel, 2015).

The peripheral placement of water treatment plants is not the only socio-material strategy for making the public service unobtrusive—and invisible to its beneficiaries. Only when looking back in history or when visiting less developed places, where streets are simultaneously used for transport and drainage, are we reminded of how 'multifunctional' urban streets can smell and look like. In 'modern' cities however, we have become used to above-ground cleanliness and underground sewage system (Gandy, 2014; Latour & Hermant, 2006 [1998]). Accordingly, most of us overlook the constant technical care and maintenance that sustain sewage systems despite inevitable decay, changing climate conditions and growing or shrinking urban populations. Most of us also overlook the civil engineering structures, which can well be described as master works. For instance, I was impressed when I learned during a tour around the water treatment plant in Dresden Germany that the pipes of the historic sewage system were not round, but made of V-shaped stones (see Figure 2).

Figure 2: A piece of sewer and a bucket of treated wastewater (photos: Nona Schulte-Römer) and the historical building of the Dresden water treatment plant.

Source: stadtentwaesserung-dresden.de

The tapered shape made the sewage flow faster if there was little water avoiding the blocking of the system—in my eyes a fascinating technical detail.

The tour, which I attended together with a school class, can be understood as part of Dresden's water governance. By making the public infrastructures visible to lay audience, the operators of the water treatment plant aim to shape and raise public awareness for their public services. Sensory experiences are thereby not only inevitable, but also offer sensational highlights.

The Dresden water treatment plant is situated in a peripheral urban area close to the highway. After passing the gate, our group stopped in front of a surprisingly appealing architectural ensemble, which was constructed in the 19th century as explained by the tour guide and on the website of the facility (image 2, right). Today, the buildings that used to welcome and channel the sewage through a large rake have run dry and been nicely renovated to host the visitors center where we assembled to watch a short introductory film about the history of water treatment in Dresden. The accomplished architectural design creates a stark contrast to the stinking excrements and effluents that the buildings used to contain and conceal. After the introduction, we straightly entered the buildings where the water was collected and a large rake retained the solid waste. As we moved around the untreated sewage and the conveyor belt that removed the solid waste the students giggled and covered their noses in a mixture of disgust and a sense of sensation (cf. Michael, 2020).

When we arrived outside at the big basins, the smell faded away and we relied more on our visual sense. As we walked from one basin to the next, the water looked cleaner and cleaner. Our guide made the purification process even more visible by presenting us a bucket of water at every stage of the water treatment. At the first basin, the water was muddy and turbid and it was impossible to see the bottom of the bucket. As we moved on, the water became clearer with every new bucket. As we arrived at the last basin, it was translucent and the guide assured us that the water was now clean enough to release it into the river Elbe and asked a student to smell the water in the bucket. However, he also pointed to a class of substances that are invisible to the human eye and have become known as micropollutants due to their very low doses (Schwarzenbach et al., 2006).

Micropollutants are a perfect example for an invisible environmental challenge that calls for public attention in order to be tackled. Traces of chemical substances can be found in all water bodies, including drinking water reservoirs. Experts are concerned since some plastics and pharmaceutical residues contain hormonal substances that can have adverse effects on water organisms at very low doses (Ternes & Joss, 2006). Although there is no scientific evidence that micropollutants have health effects on humans, they concern us all—as water consumers and even more importantly, as polluters. Accordingly, our Dresden tour guide did not miss the opportunity to raise the teenagers' awareness for the emerging environmental risk. "If you take drugs or the girls take the pill," he told the school class, "your urine will contain traces of these substances." He further observed that facilities like the one in Dresden are not yet prepared to filter out these tiny residues (field notes). Thus, chemical

residues are flushed through the toilet into the sewage system, pass through the water treatment plant and accumulate in the water cycle.

The issue of micropollutants nicely illustrates that invisible infrastructures and inattentional blindness can be a challenge when it comes to refurbishing public services in sustainable ways. In order to eliminate micropollutants like pharmaceutical residues, water utilities in Germany have begun to make large investments in infrastructural refurbishments and upgrade their water treatment plants with an additional, energy-intensive fourth purification stage. These sociotechnical and investments are controversially discussed among experts (Gawel, 2015). But there seems little public engagement, despite the fact that the issue concerns everyone who consumes water, pays taxes and uses pharmaceuticals or personal care products (Schulte-Römer & Söding, 2019). Engaging laypersons in this discussion and communicating the environmental risk and is also all but trivial (Jekel et al., 2013). First, micropollutants are per definition tiny and their adverse effects very difficult to grasp. As a result and fortunately, trace substances are therefore imperceptible to our bodily senses. Second, research on the adverse effects of micropollutants is ongoing. While it seems that micropollutants do not negatively affect our health, there is also a lot of non-knowledge and uncertainty (Tobias, 2016). Awareness of micropollutants nevertheless challenges the very idea of entirely pure drinking water. "We used to tell our customers that our drinking water is pure," told me the representative of Dutch drinking water supply services during a conference. "Today, we know better and say that but only claim that it is safe." As my last example shows, not all water consumers are buying that and contest their water providers truths.

2.3 Making drinking water look bad

In Germany, the societal claim for purity beyond health considerations is acknowledged in the drinking water ordinance. The principle of minimizing contaminations of any kind is thereby tied to aesthetic evaluative criteria. Drinking water consumers should not feel disgusted by the sight, taste or smell of tap water (Dieter & Mückter, 2007, p. 329). These "drinking water aesthetics" (Dieter & Mückter, 2007; Dietrich & Burlingame, 2015) are also reflected in the German norm on drinking water supply DIN 2000. According to this norm, "drinking water should be 'appetizing'" and as natural and unadulterated as possible (Klauer et al., 2019, pp. 105, my translation). The following episode illustrates how sensory qualities can undermine the idea of pure water and with it, the idea of trustworthy public water services. It took place in a vegan restaurant in the German city of Leipzig as part of an information event on water filters on a weekday evening in 2017.

Figure 3: A new and a used cotton filter, the rusty inside of a drinking water pipe and an experimental setting with a bowl of tea made with filtered water (left) and one with unfiltered tap water (right).

Source: Nona Schulte-Römer

The purpose of the meeting was clear from the start—the promotion of a water filter system by a Berlin company. The host was not employed by the company but an ardent advocate of the filters and convinced of the bad quality of German drinking water. During the event, he eloquently presented what he described as marginalized scientific findings about the bad quality and potential adverse effects of our drinking water. More importantly, however, he exposed parts of urban water supply systems that are usually hidden from view and offered his audience a series of impressive sensory experiences. In particular, he gave us the opportunity to taste with our own mouth and see with our own eyes the differences between the filtered and the ordinary unfiltered, but still controlled and treated Leipzig tap water. While the presentations appeared like quasi-scientific experiments or tests, the framing of the situation was non-scientific. Their purpose was not to explore a specific research question but to illustrate in a sensory way that local drinking water was not pure—irrespective of whether the substances in the water posed a health risk or not.

An acid test, which I faintly remembered from high school, colorfully illustrated that the filtered water is less alkaline than the tap water. The experiment was impressive even if it remained unclear what the coloring really meant in terms of water quality or even health risks. A tea tasting using the two different water samples was even more convincing. As a critical, even skeptical observer of the presentation, I was utterly surprised when I found that the tea from filtered water looked indeed more appetizing and also tasted more aromatic. In addition to these demonstrations focusing on the water, the show also involved the presentation of artifacts that illustrated the detrimental and supposedly non-hygienic state of water supply infrastructures. Our host presented cotton filters that were used in drinking water

pipes and already looked disgustingly dirty after only a few days of use, as he said. He also presented a piece of a water pipe that looked utterly rusty and rotten. The presentation did not fail to make an impression on its audience, including me. Although I trust in German water treatment and although I could neither verify the authenticity of these specimens nor the truthfulness of his narrative, these sensory performances made such a strong impression on me that I even briefly considered purchasing a filter.

To conclude, the guided tour in Dresden and the water filter information event in Leipzig both reveal that the sensory qualities of water are suited to engaging water users in techno-scientific issues and sociotechnical matters that shape our daily lives and concern our wellbeing in fundamental ways. In both cases opposing affective experiences of disgust and appetizing purity played an important role. This is very much in line with Mike Michael's account of public and medial representations or "enactments" of fatbergs in London's sewage system and what he describes as "affective infrastructuring"—a way of making both public infrastructures and their audiences (Michael, 2020, p. 377). These public enactments of infrastructures and their maintenance challenges, so Michael, sustain the 'working-ness' of the system "through affective means—by shaping the affects of those audiences in which a problem such as a fatberg becomes, in one way or another, 'acceptable,' 'ignorable' or 'ironicized.'" (Michael, 2020, p. 379). This resonates with my experiences with and observations of sensory engagements with water and lighting infrastructures.

3. SENSORY GOVERNANCE: A CONCEPTUAL PROPOSITION

In order to describe aesthetic practices around infrastructures as sensory governance, it is my conceptual proposition to highlight a particular, politically relevant mode of "infrastructuring." The notion of "infrastructuring" indicates a praxeological, relational approach to sociotechnical systems (Pipek & Wulf, 2009; Star & Bowker, 2002). Sociotechnical systems are analyzed not as structural entities but as the result of "systematically linked and synchronised practices." (Korn, Reißmann, Röhl, & Sittler, 2019, p. 17). Following this methodological line, the activities described above can be understood as practices that concern our perception of public services and mitigate sensory sensitivities around sociotechnical systems and transitions. To conceptualize these practices as sensory governance draws attention to the patterns of public visibility and inattentional blindness that affect how we plan, maintain, and transition our sociotechnical systems—or leave them in the care of– planners, system operators, future-makers. To call this governance 'sensory' rather than 'aesthetic' indicates that the analytical focus differs from "a tradition of thought that understands aesthetics as the key to capturing transcendental truth in sensuous forms" (Black, 2014, p. 101). Instead, 'sensory' refers to a

broad spectrum of practices that all enact the relationship between human bodies and their material sociotechnical environment by technical, scientific, aesthetic or other means. The notion 'sensory' thereby also alludes to the techno-scientific means and sensor-based practices that can expand our corporeal sensorium and are key to the (sensory) governance of sociotechnical systems (cf. Gabrys, 2016). These practices are at the center of Foucauldian power-knowledge (Foucault, 1980) and reproduce heterogeneous engagements with sociotechnical systems. Lighting planners and water treatment experts govern light and water based on techno-scientific threshold values and using measuring devices and standardized tests that laypersons neither possess, nor know to perform.

The above-described examples also show that sensory experiences of public infrastructures can vary greatly depending on local contexts and framings. Sensory experiences of sociotechnical systems are not coincidental but enacted in specific situations and institutional contexts and shaped by expectations (Shove, 2003). If sensory experiences contradict these expectations, they can produce quite different senses of water and light. Drinking water is supposed to be "appetizing," wastewater treatment should be unobtrusive. However, if presented in a certain way, drinking water can turn into something unsavory and wastewater and sewage systems can be experienced as sensational—in the context of a guided tour (2.2.) or in an exhibition about fatbergs (Michael 2020). Similarly, artificial lighting can be perceived as 'beautiful' illumination or indispensable in public spaces or else, if we look at it in the context of surveillance or consider its non-visual hormonal effects, especially cool-white light can appear as rather uncanny and even 'dangerous' (AMA, 2016; Hirdina & Augsburger, 2000).

Focusing on the observable effects of sensory governance, we can identify and broadly differentiate between three categories of practices. First, we find normalizing or 'invisibilizing' sensory practices. Their purpose is often to prevent that environmental emissions of sociotechnical systems or their visual appearance compromise their operation or public acceptance. Examples include the above-mentioned creation of and compliance with thresholds for olfactory nuisances from wastewater plants or the prevention of glare and brightness standards for street lighting. Thresholds for noise and ionized radiation also fall into this category. These threshold values are usually created on the basis of scientific experiments, while compliance often involves spatial and material planning and design, e.g., the siting of wastewater plants or LED lighting test sites in peripheral areas, the construction of street lights with a glare-reducing optical system, or the synchronization of wind park lights (Pohl et al., 2012).

Second, we find practices aimed at demonstrating or 'visibilizing' sociotechnical systems in order to reveal how they work, to inform experts and larger lay audiences about their advantages or problems, and to involve stakeholders either in the maintenance and stabilization, or in the phase-out and transition of sociotechnical sys-

tems. As outlined, such demonstrative practices can take the form of guided tours through wastewater treatment plants or illuminated urban spaces (Schulte-Römer, 2022). They are also pivotal and common in processes of technological change where stakeholder engagement and public acceptance is paramount and fostered through technology presentations in front of selected or wider audiences (David E Nye, 1996; Pinch, 2003; Simakova, 2010).

Third, aesthetizing practices aim at actively shaping sensory experiences in designerly or artistic ways. They aim at a specific form of "sense perceptions," as Andreas Reckwitz (2017, p. 64) calls it, that are "not embodied in instrumental or normative practice but rather performed for the sake of their affective effects on the subject." (Reckwitz, 2017, p. 64). In the context of sociotechnical transition, aestheticizing can be reflective in the sense that it can open a "reflective conversation" (Schön, 1992) and reveal "the complete range of implications associated with a contending array of … technological choices," including sensorial sensitivities (Stirling, 2006, p. 137). This can include pleasant decorative illuminations, appealing architectural designs for buildings that contain sewage, the greening of roofs as well as artful approaches to engaging stakeholders in infrastructural projects and visualizations in future-making. On the other hand, aesthetizing sensory governance might also divert attention away from the controversial technical issues or sociotechnical transitions and instead, engage publics in an affirmative spectacle (cf. Debord, 1970 [1967]).

Analytically, the differentiation between normalizing, demonstrating, and aesthetizing practices offers a framework for qualifying the relationship between sociotechnical enactments and sensory experiences. Through this analytical lens, we also see that not all attempts to normalize, demonstrate or aesthetize experiences of sociotechnical systems translate equally well into stable arrangements or desirable transitions. As the Mumbai example shows, the public-private company successfully implemented cool-white LEDs throughout India, but failed to normalize the infrastructural upgrade in Mumbai and at religious sites. In these places, local stakeholder groups opposed innovation by demonstrating its sensory side-effects on the sense of place. The Indian counter-enactments were successful as they were performed by a popular local politician and supported local mass media. In contrast, the maverick who enacted German drinking water as impure and in need of filtering performed from an outsider position in front of a small crowd of about twenty people. Although his sensory demonstration did not trigger a mass movement, he was able to create a momentary sense of unease that challenged the idea of perfectly well-controlled German drinking water. Aestheticizing practices are equally undetermined in their effects. Whether they challenge or maintain the order of a running sociotechnical system strongly depends on the practitioners' position and resources in a field. The Lyon lighting festival, for instance, is part of and supports the city's official urban regeneration strategy (Schulte-Römer, 2011). The Lyon public lighting service thereby

actively contributes to what Andreas Reckwitz described as a self-culturalization of cities" (Reckwitz, 2009). Critical reflective conversations that draw attention to social inequalities in public lighting are enacted elsewhere, e.g., in the form of participatory interventions as they are performed by the Guerilla Lighting collective together with local citizens (Sloane, Slater, & Entwistle, 2016). Masato Fukushima describes yet another aesthetic practice, namely the "artialisation" of ugly infrastructures in the form of artistic representations that opens a reflective conversation about "noise in the landscape" (Fukushima, 2020). Historian David Nye (1996) makes a similar point when he refers to modern American infrastructures as performances of the "technological sublime."

Last but not least, the difference between the often successful sensory governance of those in charge of infrastructures, e.g. system builders and public services, and the sensory counter-enactments of their observers resonates with Michel de Certeau's distinction between strategies and tactics (de Certeau, 1984, 2005). In his view, "a tactic is a calculated action determined by the absence of a proper locus" and hence, by the absence of autonomy. "The space of a tactic is the space of the other. Thus it must play on and with a terrain imposed on it and organized by the law of a foreign power" (2005, p. 219). A strategy in contrast, is "the calculation (or manipulation) of power relationships" performed by actors "with will and power (a business, an army, a city a scientific institution) can be isolated. It postulates a place that can be delimited as its own and serve as the base from which relations with an exteriority composed of targets or threats (customers or competitors, enemies, the country surrounding the city, objectives and objects of research, etc.) can be managed" (2005, p.18). Accordingly, experts enact their own sensory relationships with infrastructure and shape the sensory sociotechnical engagements of others from institutionalized positions within their respective techno-scientific fields and in line with established power/knowledge (cf. Lemke, 2001). This techno-scientific "locus" is stabilized and reproduced through institutional settings, standardized methods and procedures, rules, and professional norms. Lighting experts can rely on photometric knowledge and standards (ILP – Institution of Lighting Professionals, 2011), water experts on evidence and norms regarding the organoleptic properties of water (Dietrich & Burlingame, 2015). In short, their sensory governance is based on resources, including standards, measuring devices and expert knowledge that others do not have.

In the face of sociotechnical threats like constant infrastructural decay, system failure and lack of resources, and new challenges like climate adaptation, sustainable development, digitalization, and cyber security, public impression management through sensory governance might appear like a minor issue. However, current public controversies and protest against sustainability-oriented sociotechnical transitions suggest that sensory experiences of sociotechnical environments are all but irrelevant as they shape the ways in which we engage with

public infrastructures in transition. This is why I conclude with a call for a more sensorily sensitive social-scientific transition research and more reflexive sensory governance.

3. CONCLUSION: SENSORY BLINDSPOTS OF SOCIOTECHNICAL TRANSITIONS

Artificial lighting and water treatment are only two areas where sensory management practices affect and distinguish the ways in which experts and their larger audiences engage with public infrastructures and infrastructural transitions. There are numerous examples in the context of energy transitions, but also around introduction of 5G telecommunication networks or in the mobility sector where experts and their lay observers do not share the same sensory experiences. While the experts are closely entangled and deeply sensitive to the technology in their care, often aided by sensing devices, lay audiences and users of sociotechnical systems usually pay little attention and take their sensory sociotechnical environment for granted, until something changes. These differences are not coincidental but shaped by sociocultural practices of sensing with all senses, which also produces expert ways of seeing, touching or tasting (Goodwin, 1994; Hennion, 2007; Parolin & Mattozzi, 2013; Vertesi, 2015). But that is not all. As I have outlined in this chapter, system builders, transition managers and their opponents also engage in practices that are designed to shape human sensory experiences. Compared to technological and economic issues, such sensitivities have so far received rather little attention in both theory and practice although they can negatively affect the acceptance and progress of infrastructural projects.

The concept of *sensory governance*, which I have proposed in this article, highlights these practices and allows us to examine how they affect the ways in which we relate and engage with the ubiquitous sociotechnical systems around us. Doing so, we see that in most cases, sensory governance facilitates a very pleasant division of labor, allowing users of public services and infrastructures to remain ignorant of infrastructural work and leave the planning and maintenance to experts. This kind of invisibility is a wonderful sociocultural achievement and makes our lives easier. Yet, it also causes problems or, more precisely, a dilemma: The less we are able to experience public services and infrastructure, the less opportunities we have to engage with them in mundane as well as political ways. If infrastructural issues are removed from the public eye, it becomes more difficult to spark stakeholder engagement and create awareness for risks and critical issues (Kuchinskaya, 2014). The dilemma is even more obvious if we consider sensory governance as a way of *doing* subjective sensorial perception as a basis for collective sense making. Then we see that the predominant *normalizing* sensory practices help stabilize and maintain the taken-for-

granted status quo. But they are less suited to opening debates about how outdated infrastructures should be transformed for the common good and what resilience or sustainability means in a specific urban context. Yet, in the course of infrastructural transitions and refurbishments providers of public infrastructure seek and rely on their clients' feedback, acceptance, and cooperation as can be observed in the field of lighting or the water (Deleuil, 2009; Ferguson et al., 2013). After all, infrastructures are planned, built, and maintained with tax money in public spaces and used by the people.

Normalizing practices of sensory governance can also have more serious side effects as it makes it impossible for a population to see the signs of and anticipate system failures. Blackouts hit our digitalized society hard, and failing water infrastructures become a deadly danger in the event of floods, droughts or contamination. In this regard *demonstrating* sensory governance practices gains importance as a means to strategically draw attention to the material, but often invisible weak points of existing sociotechnical systems, e.g., micropollutants that can only be fixed with costly infrastructural refurbishments or more sustainable water and land uses (2.2.). Experts' strategic visibilization of infrastructures can thus play an important role when it comes to raising public awareness, interest, and even pride in local infrastructures (cf. Larkin, 2013; Michael, 2020). At the same time, the example of the Leipzig water-filter presentation shows that demonstrating practices can also be tactics aimed at contesting existing power/knowledge (de Certeau, 1984; Foucault, 1980). This repertory of contesting tactics also includes *aesthetizing* practices as the case of the Mumbai and Berlin protests against LEDs nicely illustrate. In both cases, opponents of the sociotechnical transition towards LED lighting referred to the pleasure of experiencing a specific atmosphere in what they depicted as a unique, culturally valuable place in order to prevent their governments' plan to modernize existing infrastructure.

Sociotechnical controversies also "provide a plethora of examples for public mobilisation in societies of 'reflexive modernization'…," says political scientist Sigrid Baringhorst (2019, p. 70; cf. Beck, Giddens, & Lash, 1994). In this context, controversies over sensory issues offer an important starting point for analyzing and understanding competing strategies and tactics of sensory governance opening up a space of reflexivity that has been widely neglected in sociotechnical transition processes and transition research (cf. Köhler, Geels, Kern, Onsongo, & Wieczorek, 2017). This lack of reflexivity regarding the sensory dimension of infrastructural projects and sustainability transitions is somewhat surprising as the tangible materiality of infrastructures and sociotechnical systems has always been an issue (Bijker, Hughes, & Pinch, 1987; Latour, 2000), while aesthetic questions have always played a key role in modern critique, from Walter Benjamin to Theodor W. Adorno. In order to explore this untapped potential for reflexivity, I therefore propose to focus on situated practices of sensory governance and to empirically study how

they facilitate or undermine societal engagement with infrastructural projects and sociotechnical transitions towards sustainability. The claim is that, if we are to understand public ignorance and opposition, we cannot just focus on the hard facts and objectified indicators. We also need to observe and reflect on how people experience their familiar sociotechnical environment in sensory ways. The history of sociotechnical transitions is full of examples where system builders paid great attention to governing the sensory dimension of their innovations. Just think of Thomas A. Edison, who buried his electricity lines underground and sold his light bulb in lamps that looked familiar gaslight chandeliers (Bazerman, 1999). However, there are also numerous and notorious cases where transition managers manage individual sensory experiences in standardized ways—based on photometric tests or with reference to "normal noses"—and cannot relate to their clients' individual sensitivities. Evidence-based and institutionally established as these practices are, it is difficult to contest the infrastructural realities they constitute. Where the common infrastructural good is at stake, personal unease and sensory experiences that contradict the objectified reality of this established power/knowledge are therefore often dismissed as marginal subjective sensitivities. For instance, the negatively connoted notion of NIMBYism (for "not in my back yard," cf. Devine-Wright, 2014) often stigmatizes people's legitimate protest against a profound and noticeable transformation of their immediate living environment from a rational cognitivist point of view as backward-looking, selfish, and environmentally unfriendly. Likewise, adherence to statistical approaches and the focus on the average sensory experience of populations, passes over the fact that individuals within a population experience differently due to both their physiological and cultural constitution. Accordingly, light-sensitive people who feel heavily affected by LED flicker were extremely disappointed when an EU risk assessment report only accounted for scientific evidence on LED-related health effects on healthy 'normal' people (LightAware, 2020; SCHEER, 2018). Numerous other cases show how hard it can be to gain public recognition and responses for infrastructure-related sensory tangible environmental impacts like the "sick building syndrome" (Murphy, 2006), polluted air or polluted water (Brown, 1992).

All these examples show that people engage with sociotechnical systems and transition in ways that not merely based on reason but also as a result of bodily sensitivities (cf. Marres, 2007). These engagements are relevant as they cause conflicts, slow down or even change the course of well-meant infrastructural projects like the LED refurbishments in Mumbai or Berlin or the installation of wind parks. In this regard, the focus on sensory governance can reveal that experts' and laypersons engagement with sociotechnical systems is not only enacted in different modes (Thévenot, 2007) but also actively shaped in different ways. It can also highlight how less established tactics facilitate public engagements 'by other means,' as outlined in science and technology studies (STS). Such practices can include participatory

research, citizen science and environmental sensing techniques (Gabrys, 2016; Gramaglia & Mélard, 2019; Kuchinskaya, 2019), which not only visibilize sociotechnical issues but also affect the ways in which we relate to our sociotechnical environments. They also include artistic performances that enact sociotechnical relationships in aestheticized ways (cf. Mukherjee, 2016).

The theoretical implication of reflections on sensory governance is that it seems worthwhile integrating and considering this sensory dimension as important for "reflexive governance" (J.-P. Voß, Bauknecht, & Kemp, 2006). To put it in Scott Lash's words: "reflexivity must also importantly be aesthetic. That is, that subjectivity is reflective not just through cognitive (or indeed normative) categories, but also through an aesthetic prism" (1993, p. 2). This reflexivity creates and challenges our modern entanglements in sensory rather than purely conceptual ways. They draw out attention to how sociotechnical relationships are facilitated or marginalized in the first place, even before a word has been spoken. Science and technology studies offer numerous and rich accounts and approaches that are instructive for exploring the heterogeneous ways in which sensory engagement and affects are enacted (Parolin & Mattozzi, 2013; Tironi, 2018) and how affective, sensory experiences shape intimate and public engagements (Gomart & Hennion, 1998; Marres, 2012; Michael, 2020). Looking from a legal perspective, Sheryl Hamilton has proposed the notion of "sensuous governance" to explore and question the "particular sensory knowledge-making practices and knowing systems" that form the basis for "the myriad ways in which sensing—embodied being, experiencing, and inter-acting in the world—is integrated into the juridification of social life." (2020, p. 2). However, this research has not yet found its way into transition discourses and research (Köhler et al., 2017). Exceptions include attempts to "remake participation" through more reflexive formats and forms of stakeholder engagement that also reflect the sensorial materiality and entanglements of sociotechnical issues (Le Dantec, 2016; Chilvers, 2013; J. P. Voß & Guggenheim, 2019). Against this background, the notion of sensory governance entails the proposition to reflexively explore the ways in which stakeholders manage sensory experiences and mitigate the subjective experiences with objectified power-knowledge or contest objectified experiences. It implies a mode of reflexivity that comprises aesthetics as well as sociotechnical sensing practices and opens reflective conversations on how we experience the world. The practical relevance of this proposition lies in a better understanding of how people engage, ignore or oppose sociotechnical matters based on subjective sensory experiences.

References

AMA (2016). Report of the Council on Science and Public Health on Human and Environmental Effects of Light Emitting Diode (LED) Community Lighting.

Presented by Luis J. Kraus, MD, Chair. In *CSAPH Report 2-A-16*. https://www.ama-assn.org/sites/ama-assn.org/files/corp/media-browser/public/about-ama/councils/Council%20Reports/council-on-science-public-health/a16-csaph2.pdf.

Aora, N. N. (2015 July 7). In Mumbai, How Queen's Necklace Should Glow Turns into a Battle. Retrieved from https://www.ndtv.com/mumbai-news/court-suggests-return-of-golden-queens-necklace-mumbaikars-happy-778846.

Baringhorst, S., Marres, N., Shove, E., & Wulf, V. (2019). How Are Infrastructures and Publics Related and Why Should We Care? An Email Conversation. In M. Korn, W. Reißmann, T. Röhl, & D. Sittler (Eds.), *Infrastructuring Publics. Medien der Kooperation.* . Wiesbaden: Springer VS.

Bazerman, C. (1999). *The Languages of Edison's Light*. Cambridge, MA: MIT Press.

Beck, U., Giddens, A., & Lash, S. (1994). *Reflexive modernization: Politics, tradition and aesthetics in the modern social order.* Stanford, CA: Stanford University Press.

Bijker, W. E., Hughes, T. P., & Pinch, T. J. (1987). *The social construction of technological systems: New directions in the sociology and history of technology*. Cambridge, MA: MIT Press.

Bille, M. (2019). *Homely Atmospheres and Lighting Technologies in Denmark: Living with Light*. London, UK: Bloomsbury Publishing.

Black, D. (2014). An aesthetics of the invisible: nanotechnology and informatic matter. *Theory, Culture & Society, 31*(1), 99–121.

Bogner, A. (2012). The paradox of participation experiments. *Science, Technology, & Human Values, 37*(5), 506–527.

Boltanski, L., & Thévenot, L. (2006). *On justification: Economies of worth* (C. Porter, Trans.). Princeton, NJ: Princeton University Press.

Bowker, G. C., & Star, S. L. (1999). *Sorting things out*. Cambridge, MA: MIT Press.

Brown, P. (1992). Popular epidemiology and toxic waste contamination: lay and professional ways of knowing. *Journal of health and social behavior, 33*(3), 267–281.

Bruner, J. (1986). *Actual minds, possible worlds*. Cambridge, MA: Harvard University Press.

Buck-Morss, S. (1992). Aesthetics and anaesthetics: Walter Benjamin's artwork essay reconsidered. *October, 62*, 3–41. Cambridge, MA: MIT Press.

Chilvers, J. (2013). Reflexive engagement? Actors, learning, and reflexivity in public dialogue on science and technology. *Science Communication, 35*(3), 283–310.

Chilvers, J., & Kearnes, M. (2015). *Remaking participation: Science, environment and emergent publics*. London, UK: Routledge.

Collier, S. J., Mizes, J. C., & Von Schnitzler, A. (2016). Preface: Public infrastructures/infrastructural publics. *Limn, 7* (July).

Dantec, C. A. L., & DiSalvo, C. (2013). Infrastructuring and the formation of publics in participatory design. *Social studies of science, 43*(2), 241–264.

De Certeau, M. (1984). *The practice of everyday life.* Berkeley, CA: University of California Press.

De Certeau, M. (2005). Making do": uses and tactics. In G. Spiegel (Ed.), *Practicing history: New directions in historical writing after the linguistic turn* (Vol. 217, pp. 213–223). London, UK: Routledge.

De França Doria, M. (2010). Factors influencing public perception of drinking water quality. *Water Policy, 12*(1), 1–19. doi:10.2166/wp.2009.051

Debord, G. (1970). *Society of the Spectacle* (D. Nicholson-Smith, Trans.). Detroit, MI: Black & Red. (Original work published 1967)

Deleuil, J. M. (Ed.) (2009). *Eclairer la ville autrement. innovations et expérimentations en éclairage public*. Lausanne, CH; Lyon, FR: Presses Polytechnique et Universitaires Romandes.

Devine-Wright, P. (2014). *Renewable Energy and the Public: from NIMBY to Participation*: London, UK: Routledge.

Dieter, H., & Mückter, H. (2007). Regulatorische, gesundheitliche und ästhetische Bewertung sogenannter Spurenstoffe im Trinkwasser unter besonderer Berücksichtigung von Arzneimitteln. *Bundesgesundheitsblatt-Gesundheitsforschung-Gesundheitsschutz, 50*(3), 322–331.

Dietrich, A. M., & Burlingame, G. A. (2015). Critical review and rethinking of USEPA secondary standards for maintaining organoleptic quality of drinking water. *Environmental Science & Technology, 49*(2), 708–720.

Djaoui, M., & Poirieux, C. (2007). *Lumières de Lyon. 8 décembre fête des lumières*. Lyon, FR: Édition lyonnaises d'Art et d'Histoire.

Edensor, T. (2017). *From Light to Dark: Daylight, Illumination, and Gloom*. Minneapolis, MN: University of Minnesota Press.

Ferguson, B. C., Brown, R. R., Frantzeskaki, N., de Haan, F. J., & Deletic, A. (2013). The enabling institutional context for integrated water management: Lessons from Melbourne. *Water Research, 47*(20), 7300–7314.

Foucault, M. (1980). *Power/knowledge: Selected interviews and other writings, 1972–1977* (C. Gordon, L. Marshall, J. Mepham, & K. Soper, Trans.). New York, NY: Pantheon Books.

Frechen, F. (1988). Odour emissions and odour control at wastewater treatment plants in West Germany. *Water Science and Technology, 20*(4–5), 261–266.

Fukushima, M. (2020). Noise in the landscape: Disputing the visibility of mundane technological objects. *Journal of Material Culture*, 26(1), 64–84.

Gabrys, J. (2016). *Program earth: Environmental sensing technology and the making of a computational planet*: Minneapolis, MN: University of Minnesota Press.

Gandy, M. (2014). *The fabric of space: Water, modernity, and the urban imagination*. Cambridge, MA: MIT Press.

Gawel, E. (2015). Fighting micropollutants: comparing the Leipzig and the Swiss model of funding quarternary wastewater treatment. *GAIA-Ecological Perspectives for Science and Society, 24*(4), 254–260.

Gomart, E., & Hennion, A. (1998). A sociology of attachment: music amateurs, drug users. *The Sociological Review, 46*(S), 220–247.

Goodwin, C. (1994). Professional vision. *American Anthropologist, 96*(3), 606–633.

Graham, S., & Thrift, N. (2007). Out of order: Understanding repair and maintenance. *Theory, Culture & Society, 24*(3), 1–25.

Gramaglia, C., & Mélard, F. (2019). Looking for the cosmopolitical fish: monitoring marine pollution with anglers and congers in the Gulf of Fos, southern France. *Science, Technology, & Human Values, 44*(5), 814–842.

Hamilton, S. N. (2020). Introduction: Sensuous governance. *The Senses and Society, 15*(1), 1–8. doi:10.1080/17458927.2020.1726059

Hennion, A. (2004). Pragmatics of taste. In M. Jacobs & N. Hanrahan (Eds.), *The Blackwell Companion to the Sociology of Culture* (pp. 131–144). Oxford: Blackwell.

Hennion, A. (2007). Those Things That Hold Us Together: Taste and Sociology. *Cultural Sociology, 97*(1), 97–114.

Hirdina, K., & Augsburger, J. (Eds.). (2000). *Schönes gefährliches Licht. Studien zu einem kulturellen Phänomen*. Stuttgart, DE: ibidem Press.

ILP – Institution of Lighting Professionals. (2011). *Guidance Notes for the Reduction of Obtrusive Light*.

Isenstadt, S., Petty, M. M., & Neumann, D. (2015). *Cities of light: Two centuries of urban illumination*: London, UK: Routledge.

Jekel, M., Ruhl, A. S., Meinel, F., Zietzschmann, F., Lima, S. P., Baur, N., …Mutz, D. (2013). Anthropogenic organic micro-pollutants and pathogens in the urban water cycle: assessment, barriers and risk communication (ASKURIS). *Environmental Sciences Europe, 25*(1), Article 20. doi:10.1186/2190-4715-25-20

Jensen, C. B., & Morita, A. (2015). Infrastructures as ontological experiments. *Engaging Science, Technology, and Society, 1*, 81–87.

Klauer, B., Aicher, C., Bratan, T., Eberle, U., Hillenbrand, T., Kümmerer, K., . . . Schramm, E. (2019). Arzneimittelrückstände in Trinkwasser und Gewässern. In *TAB-Arbeitsbericht* (Vol. 183). Berlin, DE: Büro für Technikfolgen-Abschätzung beim Deutschen Bundestag (TAB).

Köhler, J., Geels, F., Kern, F., Onsongo, E., & Wieczorek, A. (2017). A research agenda for the Sustainability Transitions Research Network. *Sustainability Transitions Research Network (STRN)*, Manchester, UK: Sustainable Consumption Institute, University of Manchester.

Korn, M., Reißmann, W., Röhl, T., & Sittler, D. (2019). *Infrastructuring Publics*: Berlin, DE: Springer.

Kuchinskaya, O. (2014). *The politics of invisibility: Public knowledge about radiation health effects after Chernobyl*. Cambridge, MA: MIT Press.

Kuchinskaya, O. (2019). Citizen science and the politics of environmental data. *Science, Technology, & Human Values, 44*(5), 871–880.

Larkin, B. (2013). The politics and poetics of infrastructure. *Annual review of anthropology, 42*, 327–343.

Lash, S. (1993). Reflexive modernization: The aesthetic dimension. *Theory, Culture & Society, 10*(1), 1–23.

Lash, S. (2018). *Experience: New Foundations for the Human Sciences*. Hoboken, NJ: John Wiley & Sons.

Latour, B. (Ed.) (2000). *The Berlin key or how to do words with things*. London, UK: Routledge.

Latour, B., & Hermant, E. (2006 [1998]). Paris: invisible city [Paris ville invisible]. Retrieved from http://www.bruno-latour.fr/virtual/EN/index.html. Retrieved 02/10/11 http://www.bruno-latour.fr/virtual/EN/index.html

Le Dantec, C. A. (2016). *Designing publics*. Cambridge, MA: MIT Press.

Lebrero, R., Bouchy, L., Stuetz, R., & Muñoz, R. (2011). Odor Assessment and Management in Wastewater Treatment Plants: A Review. *Critical Reviews in Environmental Science and Technology, 41*(10), 915–950. doi:10.1080/10643380903300000

Lemke, T. (2001). 'The birth of bio-politics': Michel Foucault's lecture at the Collège de France on neo-liberal governmentality. *Economy and society, 30*(2), 190–207.

LightAware. (2020). How does artificial lighting affect human health and wellbeing?

Lintz, G., & Leibenath, M. (2020). The politics of energy landscapes: the influence of local anti-wind initiatives on state policies in Saxony, Germany. *Energy, Sustainability and Society, 10*(1), Article 5. doi:10.1186/s13705-019-0230-3

Lukose, A. (2015, March 4). Explained: LED vs yellow lights for Queen's Necklace. Retrieved from: https://indianexpress.com/article/explained/explained-led-vs-yellow-lights-for-queens-necklace/.

Marres, N. (2007). The Issues Deserve More Credit: Pragmatist Contributions to the Study of Public Involvement in Controversy. *Social studies of science, 37*(5), 759–780.

Marres, N. (2012). *Material participation: technology, the environment and everyday publics*. Basingstoke, UK: Palgrave Macmillan.

Meier, J. M. (2018). Contentious Light: An Analytical Framework for Lighting Conflicts. *International Journal of Sustainable Lighting, 20*(2), 62–77.

Michael, M. (2020). London's fatbergs and affective infrastructuring. *Social studies of science*, 50(3), 377–397.

Mukherjee, R. (2016). Toxic Lunch in Bhopal and Chemical Publics. *Science, Technology & Human Values, 41*(5), 849–875. doi:10.1177/0162243916645196

Murphy, M. (2006). *Sick building syndrome and the problem of uncertainty: Environmental politics, technoscience, and women workers*. Durham and London, UK: Duke University Press.

Nye, D. E. (1996). *American technological sublime*. Cambridge, MA: MIT Press.

Nye, D. E. (2010). *When the Lights Went Out: A History of Blackouts in America* (Vol. 80). Cambridge, MA: MIT Press.

Parolin, L. L., & Mattozzi, A. (2013). Sensitive translations: Sensitive dimension and knowledge within two craftsmen's workplaces. *Scandinavian Journal of Management*, *29*(4), 353–366.

Pinch, T. (2003). Giving Birth to New Users. How the Minimoog Was Sold to Rock and Roll. In N. Oudshoorn & T. Pinch (Eds.), *How Users Matter The Co-Construction of Users and Technology* (pp. 247–270). Cambridge, MA: MIT Press.

Pipek, V., & Wulf, V. (2009). Infrastructuring: Toward an integrated perspective on the design and use of information technology. *Journal of the Association for Information Systems*, *10*(5).

Pohl, J., Hübner, G., & Mohs, A. (2012). Acceptance and stress effects of aircraft obstruction markings of wind turbines. *Energy Policy*, *50*, 592–600.

Reckwitz, A. (2009). Die Selbstkulturalisierung der Stadt. Zur Transformation moderner Urbanität in der "creative city." *Mittelweg 36*, *18*(2), 2–34. Retrieved from http://www.eurozine.com/articles/2009-05-20-reckwitz-de.html

Reckwitz, A. (2017). How the senses organise the social. In *Praxeological political analysis* (pp. 75–66). London, UK: Routledge.

Royal Swedish Academy of Science. (2014, October 7). Efficient blue light-emitting diodes leading to bright and energy-saving white light sources. *Scientific Background on the Nobel Prize in Physics 2014*. Retrieved from https://www.nobelprize.org/uploads/2018/06/advanced-physicsprize2014.pdf.

SCHEER – Scientific Committee on Health Environmental and Emerging Risks. (2018). Final Opinion on potential risks to human health of Light Emitting Diodes (LEDs). In R. M. Ion, A. Proykova, T. Samaras, et al. (Eds.), *DG Health and Food Safety, Directorate C: Public Health, Country Knowledge, Crisis management Unit C2—Country Knowledge and Scientific Committees*. Brussels, BE: European Commission. Retrieved from https://ec.europa.eu/health/sites/health/files/scientific_committees/scheer/docs/scheer_o_011.pdf

Schön, D. A. (1992). Designing as reflective conversation with the materials of a design situation. *Knowledge-based systems*, *5*(1), 3–14.

Schulte-Römer, N. (2011). Enlightened cities. Illuminations for urban regeneration. In F. Eckardt & S. Morgado (Eds.), *Understanding the Post-Industrial City* (pp. 128–165). Würzburg, DE: Königshausen & Neumann.

Schulte-Römer, N. (2015). *Innovating in public. The introduction of LED lighting in Berlin and Lyon*. (Doctoral thesis). Berlin, DE: Technical University Berlin, http://dx.doi.org/10.14279/depositonce-4908.

Schulte-Römer, N. (2022). Spaces for experience—lighting design as an epistemic approach. In S. Sumartojo (Ed.). New York, NY: Routledge.

Schulte-Römer, N., Bleicher, A., & Groß, M. (2017). *Can you feel the energy? The 'Sensory Governance' of energy technologies and systems*. UFZ Energy Days 2017. Leipzig, DE: Helmholtz-Centre for Environmental Research – UFZ.

Schulte-Römer, N., Dannemann, E., & Meier, J. (2018). *Light Pollution—A Global Discussion*. Retrieved from http://www.ufz.de/index.php?en=20939&ufzPublicationIdentifier=21131

Schulte-Römer, N., Meier, J., Söding, M., & Dannemann, E. (2019). The LED Paradox: How Light Pollution Challenges Experts to Reconsider Sustainable Lighting. *Sustainability, 11*(21), 6160. doi:10.3390/su11216160

Schulte-Römer, N., & Söding, M. (2019). Routine Reporting of Environmental Risk: The First Traces of Micropollutants in the German Press. *Environmental Communication, 13*(8), 1108–1127. doi:10.1080/17524032.2019.1592004

Schwarzenbach, R. P., Escher, B. I., Fenner, K., Hofstetter, T. B., Johnson, C. A., Von Gunten, U., & Wehrli, B. (2006). The challenge of micropollutants in aquatic systems. *Science, 313*(5790), 1072–1077.

Sharp, L. (2017). *Reconnecting people and water: Public engagement and sustainable urban water management*. London, UK: Taylor & Francis.

Shove, E. (2003). *Comfort, cleanliness and convenience: The social organization of normality*. Oxford, UK: Berg.

Simakova, E. (2010). RFID 'Theatre of the proof': Product launch and technology demonstration as corporate practices. *Social studies of science, 40*(4), 549–576

Sloane, M., Slater, D., & Entwistle, J. (2016). Tackling social inequalities in public lighting. A report by the configuring light/staging the social research programme. *Configuring Light/Staging the Social*. London, UK: London School of Economics and Political Science

Star, S. L., & Bowker, G. C. (2002). How to Infrastructure. In L. A. Lievrouw & S. Livingstone (Eds.), *Handbook of new media: Social shaping and consequences of ICTs* (pp. 151–162). London, UK: Sage.

Star, S. L., & Ruhleder, K. (1996). Steps toward an ecology of infrastructure: Design and access for large information spaces. *Information systems research, 7*(1), 111–134.

Stirling, A. (2006). Precaution, foresight and sustainability. Reflection and reflexivity in the governance of science and technology. *Reflexive governance for sustainable development. Cheltenham: Elgar*, 225–272.

Ternes, T., & Joss, A. (2006). *Human pharmaceuticals, hormones and fragrances. The challenge of micropollutants in urban water management*. London, UK: IWA publishing.

Thévenot, L. (2007). The Plurality of Cognitive Formats and Engagements. Moving between the Familiar and the Public. *European Journal of Social Theory, 10*(3), 409–423.

Tironi, M. (2018). *Regimes of perceptibility and cosmopolitical Sensing: The earth and the ontological politics of sensor technologies*. London, UK: Taylor & Francis.

Tobias, R. (2016). Communication About Micropollutants in Drinking Water: Effects of the Presentation and Psychological Processes. *Risk Analysis, 36*(10), 2011–2026. doi:10.1111/risa.12485

UBA, U. (2015, December 2). Drinking water in Germany once again "very good." In *Threshold values rarely exceeded—nitrate could become a cost driver for some waterworks*. Dessau, DE: Umweltbundesamt.

Ureta, S. (2014). Normalizing Transantiago: On the challenges (and limits) of repairing infrastructures. *Social studies of science, 44*(3), 368–392.

Vertesi, J. (2015). *Seeing like a rover: How robots, teams, and images craft knowledge of mars*. Chicago, IL: University of Chicago Press.

Voß, J.-P., Bauknecht, D., & Kemp, R. (2006). *Reflexive governance for sustainable development*. Cheltenham, UK: Edward Elgar Publishing.

Voß, J. P., & Guggenheim, M. (2019). Making taste public: Industrialized orders of sensing and the democratic potential of experimental eating. *Politics and Governance, 7*(4), 224–236.

Zerubavel, E. (2015). *Hidden in plain sight: The social structure of irrelevance*. New York, NY: Oxford University Press.