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Negative Luminescence

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The increasingly pervasive phenomenon of light pollution spans several different fields of concern, including the loss of the night sky, energy wastage, and the effects of artificial light on circadian rhythms and nocturnal ecology. Although the scale of the problem has grown significantly in recent decades, the underlying dynamics remain only partially understood beyond the identification of specific technological pathways such as the rise of light-emitting diodes (LEDs) or the capitalist transformation of the nocturnal realm. It is suggested that current approaches to the study of light, including the identification of "urban atmospheres," the elaboration of existing approaches to urban ecology, or the extension of "smart city" type discourses, do not capture the full complexity of the politics of light under late modernity. *Key Words: light pollution, nocturnal ecology, urban atmospheres, urban infrastructure.*

逐渐普及的光害现象, 延伸至若干不同领域的考量, 包括夜空的丧失, 能源的浪费, 以及人造光对于二十四小时生理节奏及夜间生态的影响。尽管该问题的规模在近数十年来已显着扩大, 但在指认诸如发光二极管(LEDs)的兴起或夜间领域的资本变迁等特定技术途径之外, 其基础动态仍仅受到部分理解。本文主张, 研究光的当前取径, 包括指认"城市大气"、阐述城市生态的既有路径, 抑或是延伸"智能城市"的论述类型, 皆无法完全捕捉晚现代中的光政治之复杂性。 *关键词: 光害, 夜间生态, 城市大气, 城市基础建设。*

El fenómeno cada vez más generalizado de polución luminosa abarca varios campos diferentes de preocupación, incluyendo la pérdida del cielo nocturno, el desperdicio de energía y los efectos de la luz artificial sobre los ritmos circadianos y la ecología nocturna. Aunque la escala del problema ha crecido significativamente en décadas recientes, la dinámica subyacente sigue siendo solo parcialmente entendida más allá de la identificación de específicas avenidas tecnológicas tales como el desarrollo de los diodos generadores de luz (LEDs) o la transformación capitalista del reino nocturno. Se sugiere que los enfoques actuales relacionados con el estudio de la luz, incluyendo la identificación de las "atmósferas urbanas," el desarrollo de los enfoques actuales sobre ecología urbana, o la extensión de los discursos tipo "ciudad inteligente", no captan la completa complejidad de las políticas de la luz bajo tardía modernidad. *Palabras clave: polución luminosa, ecología nocturna, atmósferas urbanas, infraestructura urbana.*

> The urban is most forcefully evoked by the constellation of lights at night, especially when flying over a city—the dazzling impression of brilliance, neon, street signs, streetlights, incitements of various kinds, the simultaneous accumulation of wealth and signs.
>
> —Henri Lefebvre[1]

> Every night, in the cities, along the streets enchanted by artificial light, there are millions of insects extinguished by the burning bulbs.
>
> —Patrick Chamoiseau[2]

Artificial light has long served as an indicator of modernity just as its converse—the urban blackout—has exposed the vulnerability of cities to infrastructure failure, wartime exigencies, or even social disorder. Yet urban illumination is more complex than the "switching off" scenario might suggest: the urban night is characterized by a chiaroscuro of different light sources producing a myriad of cultural, metabolic, and sociotechnical interactions encompassing both human and nonhuman nature alike. Light forms part of the choreography of urban life, guiding different types of activities or mobilities, generating perceived boundaries and differences, and also interfacing with the circadian rhythms of the city.

Although light is widely conceived as synonymous with modernity, we should not forget earlier efforts to illuminate human settlements with candles, fires, or flaming torches. It is not the encounter with artificial

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light per se that opens up the nocturnal realm of modernity but its accelerating rate of introduction, its steady increase in brilliance, its filamentous extension into every sociospatial sphere, and its imbrication with new forms of sensory routinization. In the case of England, for example, the current production of artificial light is estimated to be at least 350,000 times greater than that of the late sixteenth century. At a contemporary global scale, differences in annual light consumption vary widely from around 3 megalumen hours per capita in India to more than 100 megalumen hours in North America (International Energy Agency 2006).[3]

Light forms a powerful adjunct to teleological readings of the progressive rationalization of urban space. On closer inspection, however, the transition from various types of oil or tallow lanterns, to gas, and finally electricity, contains many different elements, phases, and unexpected juxtapositions. Urban illumination comprises a medley of pathway dependencies that have contributed toward the emergence of complex material landscapes of artificial light. "The nineteenth century is the history," suggests Chris Otter (2008, 261), "not of the rise of electricity or even of gaslight, but of the proliferation, concatenation, and spatial juxtaposition of multiple light forms." Similarly, the twentieth century, although increasingly dominated by electricity, reveals significant variations between buildings, neighbourhoods, and even metropolitan regions. The contemporary city is best conceived as an elaborate palimpsest where remnants of the past are juxtaposed with new elements: some functional gaslight networks remain, as in parts of the former island city of West Berlin and along London's Embankment, and commonly used streetlights such as high-pressure sodium lamps are now being widely replaced by light-emitting diodes (LEDs).

The last decade has seen growing interest in the study of light. Earlier contributions from cultural history, urban sociology, and science and technology studies have been extended to include new insights from anthropology, geography, and other fields. The study of light pollution in particular has become an interdisciplinary terrain that extends from established areas of concern such as reduced visibility of the night sky to an emerging emphasis on biodiversity loss, the disturbance of circadian rhythms, and the expansionary dynamics of global capital.[4] With the decline of the "nocturnal commons," exemplified by diminishing access to the visual wonders of the night sky, we find that more than half of the world's population are "enveloped continuously in a penumbra of smog and high-intensity illumination" (Crary 2013, 5). Since the 1960s, and the accelerated introduction of more efficient lighting technologies, the so-called lumen growth curve has been exponential, far outpacing economic growth indicators or the extent of urban sprawl (Riegel 1973, 1288). A recent study of satellite data by the pioneering investigator Fabio Falchi finds that around 83 percent of the global population is affected by "artificial skyglow," rising to over 99 percent of the population of Europe and North America (see Falchi et al. 2016a; see Figure 1).[5] It is not only urbanization itself that has contributed to the growth of light pollution: the world's oceans glow from illuminated nets and other devices to increase catch sizes of fish, squid, and other marine creatures, and the rise of fracking and other forms of unconventional hydrocarbon extraction have produced new landscapes of gas flares that are visible from space (see Meier 2016).

Light pollution encompasses several different phenomena including "light clutter," when a myriad of different sources can cause disorientation, "light trespass" from unwanted light sources, and in particular "skyglow" produced by the scattering of light in the atmosphere where the cumulative impact can reduce night sky visibility over vast areas. Urban skyglow also has the paradoxical effect of making overcast skies appear brighter: on cloudy nights most cities now lie under a mauve or reddish shroud that extends to the horizon like a technologically induced perpetual twilight (see Kyba et al. 2011). Light pollution is not simply due to the increasing quantity of light, but also its changing quality: with the contemporary transition toward brighter "white" light, exemplified by the latest generation of metal halide and LED luminaires, there is an intensification in its social and ecological side effects.

Despite recent advances in the cartographic representation of light pollution it remains a somewhat ill-defined field of study. Local measurements are complicated not only by seasonal and meteorological differences, but also by the difficulties posed from different types of "vertical, semicylindrical and cylindrical illuminances" (Cabello and Kirschbaum 2001, 148). The wider corporeal, material, and metabolic effects of light pollution, including the impact on nocturnal ecology, remain only partially understood, although this field is now beginning to develop quite rapidly (see, for example, Rich and Longcore 2006; Davies, Bennie, and Gaston 2012; Gaston, Visser, and Hölker 2015). Our understanding of the contemporary

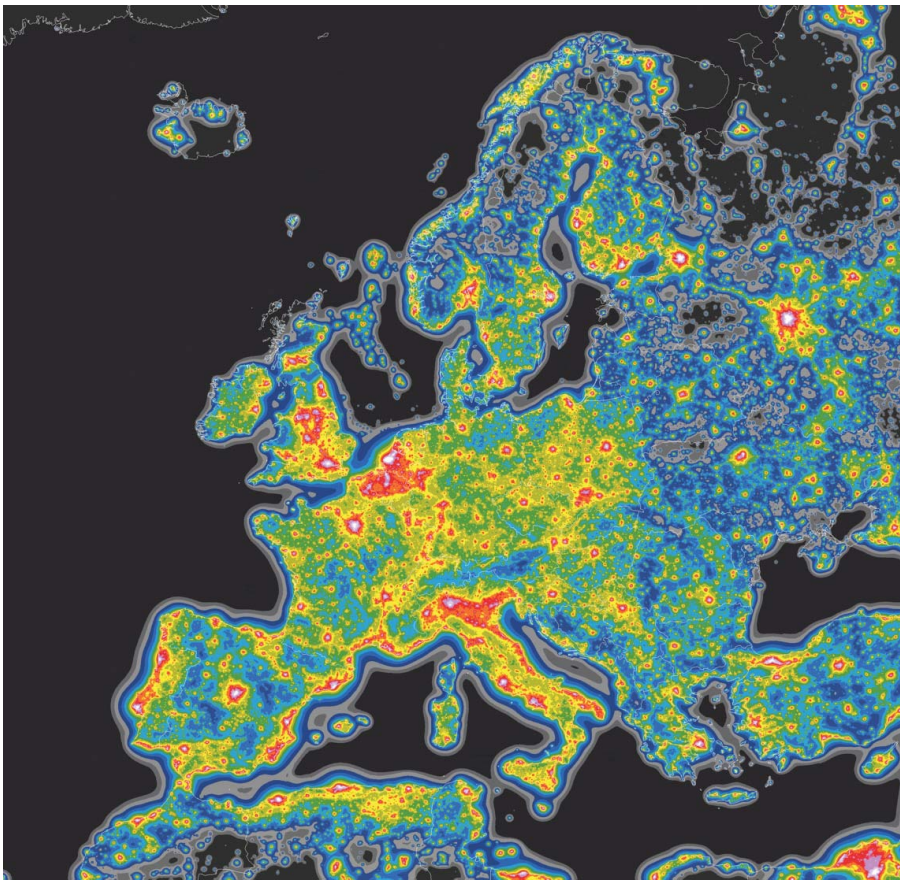

Figure 1. A cartographic representation of current levels of artificial sky brightness in Europe using low-light imaging data from the VIIRS DNB sensor on the Suomi National Polar-orbiting Partnership (NPP) satellite. The colour scale identifies areas with a ratio of artificial light ranging from less than 0.1 (with no significant light pollution) to areas with more than forty-one times the natural level of brightness. In those intermediate areas marked yellow and orange, with artificial brightness ratios of between 1.28 and 5.15, the Milky Way becomes gradually invisible. *Sources*: Falchi et al. (2016a, 2016b). (Colour figure available online.)

transition toward LED technologies remains underexplored in comparison with earlier sociotechnological pathways. Critical perspectives on nocturnal urban space, notwithstanding the earlier observations of Lefebvre and others, have scarcely touched on changing relations between light, capital, and space.

Light pollution is an interdisciplinary field par excellence. A fuller understanding of its cultural and material manifestations, and the articulation of alternative pathways, implies an engagement between disparate fields such as critical phenomenology and molecular biology. The affective scope of light extends beyond the emotional and perceptual realm to include embodied physiological dimensions to human experience and corporeal well-being (see Brennan 2004; Hölker et al. 2010). The cultural and material dimensions to light encompass both the human sensorium and multilayered entanglements of agency. The conceptual field extends from existing critiques of subjectivity within the European humanist tradition to emerging ontologies of life developed within feminist and posthuman theory (see, for example, Hayles 1999; Coole and Frost 2010). The latest scientific insights into the circadian and ecological dimensions to light pollution, including the effects of melatonin suppression on epigenetics, are not yet reflected in post-Cartesian conceptions of materiality. The affective power of light has been only partially explored in relation to the functional interdependencies and environmental externalities of global capital. A critical geography of light pollution would of necessity encompass not just its effects, but also its temporalities, its pathway dependencies, and the full scope of its multiple cultural and material denudations.

This article is structured around three interrelated facets to light pollution: first, the scale and characteristics of the increase in artificial lighting underway since the middle decades of the twentieth century; second, the periodicities and modes of interpretation that might be applied to these putative sociotechnological

transitions; and third, the intersection of light with various types of "urban atmospheres" and different manifestations of human subjectivity. We examine the cultural and material dynamics of light, spanning the biophysical realm as well as more diffuse processes, relationships, and representations. Underlying these different strands of argumentation lies the contention that modernity—or late modernity to be more precise—remains a useful lens through which to explore the changing material and sensory characteristics of urban space.

The Great Illumination

The increasing use of artificial light from the seventeenth century onward was not only a matter of convenience, safety, or nocturnal navigation, but also a means to expand economic productivity. With the steady "nocturnalization" of human activity and the "conspicuous consumption of time" we encounter a gradual separation of darkness from the modern night (Koslofsky 2011, 277). The "long night" of the mediaeval or early modern period, with its more discontinuous and seasonally related patterns of sleep, was replaced by increasingly condensed forms of rest for the "human motor" at work within glowing factories and workshops (see, for example, Rabinbach 1992; Ekirch 2001). For Karl Marx, "the prolongation of the working day beyond the limits of the natural day," through shift work or any other means available, was an indispensable component of capitalist production (Marx [1867] 1974, 245). The German writer W. G. Sebald similarly describes the blaze of light from silk weaving at night, where many workers "spent their lives with their wretched bodies strapped to looms made of wooden frames and rails, hung with weights, and reminiscent of instruments of torture or cages" (Sebald [1995] 1998, 282). These unfamiliar nocturnal landscapes not only changed the way that cities looked and felt, but also the rhythms of everyday life as the colonization of the night gathered pace.

Some of the earliest opposition to excessive lighting was provoked by the nineteenth-century introduction of arc lamps (using an arc between two carbon electrodes) as an alternative to gaslight. These powerful lights were set at double the height of existing streetlights and there were even plans to illuminate entire cities from a single vantage point.[6] Although arc lights were first used in London and Paris during the 1870s, the technology was most widely adopted in North American cities such as Austin, Detroit, and San José, especially where cheaper electricity was locally available. In the 1880s, for example, the city of Minneapolis installed its very own "electric moon" constructed from a set of arc lamps (Bouman 1987, 24). Famously decried by Robert Louis Stevenson in 1878 as "a lamp for a nightmare . . . a horror to heighten horror," the arc light was a precursor of the searchlight, and could emit a harsh and dazzling glare over long distances (cited in Schivelbusch [1983] 1988, 134). The power of arc lights was harnessed in wartime as a means to terrorize adversaries, especially by European armies engaged in wars of colonial expansionism, as illustrated by the deliberate illumination of the Egyptian port of Alexandria by the British navy in the 1880s. During World War I, arc lights were also used for the creation of "artificial moonlight" to facilitate attacks by night and in naval warfare to dazzle other ships (see Schivelbusch [1983] 1988).[7] The Promethean impulse to turn night into day has not disappeared: as recently as the 1990s, the Russian space scientist Vladimir Syromyatnikov proposed the use of giant mirrors orbiting above the earth to provide permanent daylight for strategically important construction sites (see Crary 2013; Merchant 2016).

In the twentieth century we find the first signs of concern with the effects of artificial light on the visibility of the night sky. As early as the 1930s, the Mount Wilson observatory in Southern California had begun experiencing significant problems with anthropogenic sources of "skyglow" being located just eight miles from Pasadena. By the mid-1960s, however, the far more distant Mount Palomar observatory was reporting the effects of San Diego and Los Angeles located some 60 and 90 miles away respectively. This steady deterioration led the astronomer Merle F. Walker (1973, 515) to declare that "unless adequate control of outdoor lighting can be established, work on faint objects at all of the major observatories in California and Arizona is threatened." With the replacement of incandescent streetlights with more efficient types of lamps, both the total amount of light produced and its changing wavelength began to cause significant damage to the research capacity of many leading astronomical observatories.

The contemporary term "light pollution" first begins to appear regularly from the early 1970s onward—the *Merriam-Webster Dictionary* gives 1971 as the first recorded usage, and the *Oxford English Dictionary* finds a letter to a Wisconsin newspaper dating from 1968—and extends established concerns with

the loss of the night sky to emerging anxieties over energy wastage and the aesthetic effects of artificial light (see Degenring 2015). In 1971, for example, the Sierra Club began campaigning against excessive outdoor lighting on aesthetic grounds yet public authorities did not necessarily share these objectives: in 1972, for instance, the Los Angeles City Planning Commission suggested that the Santa Monica Mountains should be permanently lit up at night with a bank of searchlights for dramatic effect (see Riegel 1973). The increasing use of light as a form of urban spectacle, notably in North American cities such as Las Vegas and Los Angeles, stands in sharp contrast with earlier "moral" concerns with the disturbance of the "natural night" that persisted well into the nineteenth century (see Brox 2010).

The growing scale of artificial illumination, as both spectacle and facilitator of capitalist urbanization, increased significantly during the second half of the twentieth century. Between the mid-1940s and the mid-1980s, for example, the city of Philadelphia saw a tripling in the number of streetlamps, a shift from tungsten filament to high-pressure sodium lamps, and a sevenfold increase in lamp intensity (see Frank 1988). Similarly, a detailed analysis of changing levels of sky brightness from astronomical observatories in the Veneto plain of northeast Italy recorded an average annual increase of 10 percent in levels of light pollution between 1960 and 1995 (see Cinzano 2000). It is not only the intensity but also the spatial extent of light that has greatly expanded: Belgium, for instance, was the first country in the world to illuminate its entire highway system from the 1970s onward and this road network is visible from space (as recalled by the homesick Belgian astronaut Frank De Winne) (Saure 2011).

Recent analysis of satellite data reveals clear regional disparities in light pollution, with relatively higher levels in parts of southern Europe, the Middle East, and East Asia: among the G20 nations the highest levels of light pollution are experienced by the populations of Saudi Arabia and South Korea and the lowest in Germany (see Falchi et al. 2016a). In South Korea, for instance, the phenomenon of "light trespass" has become increasingly significant, with homes routinely flooded by unwanted light sources (see Cha et al. 2014). The global increase in light pollution reveals different "cultures of light" exemplified by the generally darker cities of northern Europe compared with the more brightly lit cities of southern Europe (see Kyba et al. 2011). In Milan, for example, which is set to be the first European city to rely entirely on LEDs for street lighting, there are even municipal parks that are permanently illuminated despite being closed at night.

The question of light pollution is not merely a matter of human concern but also impinges on nonhuman life: the environmental effects have been recognized since the early decades of the twentieth century. Artificial light sources cause death or disorientation to huge numbers of birds, insects, and other organisms. The Statue of Liberty's flame, first lit in 1886, killed and blinded tens of thousands of birds despite its limited effectiveness as a lighthouse: in October 1887 it was recorded that 1,375 birds had died in a single night (Figure 2).[8] From the early 1950s onward there has also been concern with the disorienting effects of illuminated billboards on birds (see Hasenöhrl 2015). More recent studies have revealed the impact of artificial light on bats, fish, turtles, and many other organisms (see Rich and Longcore 2006; Held, Hölker, and Jessel 2013). It is now recognized that littoral conurbations serve as giant lighthouses that disrupt the migratory patterns of birds and insects on a vast scale (see Zilli 1998).

Most dramatic of all is the influence of light pollution on insects. The impact of artificial light on insect biodiversity is comparable in scale with the effects of insecticides and habitat destruction since at least 60 percent of invertebrates are nocturnal (see Hölker et al. 2010; Gandy 2016). Illuminated monuments, industrial flares, and other large-scale installations kill millions of moths and other insects. A solitary streetlight can kill many thousands of moths a year: if not killed directly by the heat of the lamp, moths are rendered vulnerable to an array of predators, including bats, birds, lizards, and centipedes. Swarms of moths attracted by floodlights can even disrupt major sporting events, as witnessed by the "pitch invasion" at the Stade de France during the UEFA European Championship final of June 2016.

The wider effects of light pollution on biodiversity are complex and multifaceted. Recent research suggests that moths are undergoing evolutionary adaptations such as reduced patterns of mobility that might exacerbate the effects of habitat fragmentation for smaller isolated populations (see Altermatt and Ebert 2016). Lower levels of insect mobility to avoid artificial light have implications for the pollination of plants and the functional dynamics of urban ecosystems (see Macgregor et al. 2017). The decline of bats

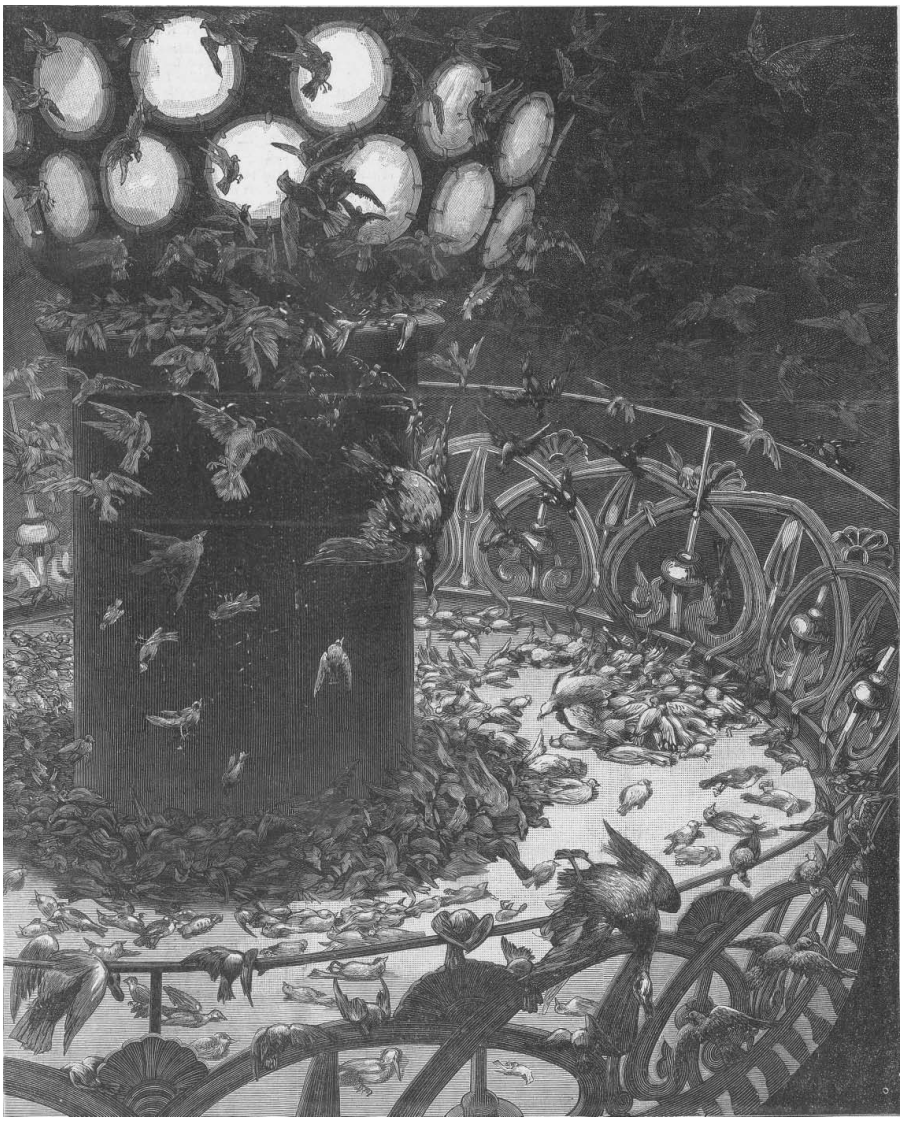

Figure 2. "Liberty's light a lure to death.—Thousands of birds blinded and killed by the flame in the statue's hand—thirteen hundred and seventy-five perish in a single night." *Frank Leslie's Illustrated Newspaper* 15 October 1887. *Source*: Sketch by a staff artist. Reproduced from the collections at the Pennsylvania State Libraries.

has adverse consequences for human well-being because they are the main nocturnal predators for mosquitoes: although they might take temporary advantage of insects attracted to artificial light, the overall decline in biomass has deleterious effects (see Stone, Jones, and Harris 2009). Streetlights have also been recorded to not only attract mosquitoes but also encourage day-flying species such as *Aedes aegypti* (the principal vector for dengue fever and the Zika virus) to bite human hosts at night (see Baldwin 2003). Light pollution also affects human health more directly: insights from chronobiology show that excess light can disrupt metabolic processes including circadian rhythms associated with rest and sleep, leading to higher rates of cancer, depression, and obesity (see, for example, Navara and Nelson 2007; O'Neill and Reddy 2011; McFadden et al. 2014; Stevens and Zhu 2015).[9]

The exponential increase in light pollution can be considered part of what J. R. McNeil and Peter Engelke (2014, 4) refer to as "the Great Acceleration," marked by a series of stark environmental indicators ranging from fossil fuel consumption to the global loss of biodiversity.[10] From this perspective the steady brightening of the earth's biosphere is merely one facet of an unprecedented juncture in global environmental history. Yet light pollution is more than just a marker for environmental disequilibria but is also a precise

outcome of the historical dynamics of sociotechnical change. The phenomenon reveals multiple pathways, imperial precedents, and proliferating zones of contestation (see Malm and Hornborg 2014). Alternative geoperspectives, including critical readings of the Anthropocene, highlight the ontological incapacities of the environmental sciences to engage with the underlying contradictions to modernity (see Parikka 2015; Wark 2015). Media theorist Jussi Parikka, for instance, introduces the term "stratification" in a double sense to evoke both the geological formations that underpin modernity and also the subsequent recombinations of biophysical matter that shape the material world. The increase in artificial light is a vivid counterpart to the wider reliance on fossil fuels that has been underway since the (forcible) advent of steam power in the industrial revolution.

Spectrums and Transitions

Light is far more than "infrastructure" in a narrow sense of technological networks, but encompasses a range of developments including material and symbolic dimensions to state formation, the coevolutionary dynamics of different modes of governmentality, and the delineation of distinctive forms of public culture ranging from the mundane to the spectacular. The increasing scope of artificial light has involved a two-way diffusion between what Annemieke Roobeek (1987, 33) terms the "auto-house-electrical-appliance complex" and emerging quasi-public spaces of consumption, entertainment, and mobility. The coevolutionary dynamics of light now connect the perceptual realm of the human body with a paraphernalia of technologies ranging from the blinking of standby lights for electronic devices to vast landscapes of artificial light.

The earliest forms of organized outside lighting consisted of oil lanterns, as used in the city of Ephesus in the time of Heraclitus (535–475 BCE), and oil remained the dominant source of lighting well into the modern era. In seventeenth-century Amsterdam, for example, oil-soaked ropes enabled the navigation of the nocturnal city (see Multhauf 1985). By 1700 some form of organized street lighting—principally by oil lanterns—was also being used in other cities such as Copenhagen, Dublin, Hamburg, London, Paris, Turin, and Vienna (see Koslofsky 2011). Oil was expensive, however, and raising taxes for these rather ineffective and unevenly distributed "city lights" proved unpopular (see Meehan 1943). With the early nineteenth-century shift from oil to gas, more elaborate networks were installed, beginning with London in 1807, followed by Paris in 1814, and then Baltimore in 1817. The period from the 1820s to the 1870s marks a steady expansion in the use of gaslight and the development of locally integrated infrastructure networks comprising coal-fired retorts, storage gasometers, and rudimentary distribution networks (see Deleuil 1995; Baldwin 2004). At first gas was widely feared or disliked, partly on account of its smell, but also due to the risk of fire or explosions (a series of terrifying theatre fires and other high-profile accidents added to this mood of unease) (see Fressoz 2007). Despite these earlier misgivings, most cities in Europe and North America had developed extensive gaslight networks by the late nineteenth century, but this merely marked a transitional phase before the emerging dominance of electricity.

The shift to electric lighting, underway from the late nineteenth century onward, was initially restricted by technical limitations, but steady improvements led to a rapid expansion in its use for fairs, parades, parks, and illuminated signage, and then eventually to the domestic interior (see O'Dea 1958; Nye 1990; Rose 1995). The shift to electricity also extended well beyond the existing epicentres of network development within Europe and North America and included cities in what is now the global South, such as Lagos, Manila, and Santiago (see Martland 2002). Beyond much of Europe and North America, however, the successive technological transitions behind the rise of artificial light have been highly fractured and uneven.

The early decades of the twentieth century saw a proliferation of manufacturers, patents, and products that created increasing volatility in the market share of dominant lighting companies such as Osram in Germany and General Electric in the United States. The development of technical innovations such as brighter and longer lasting incandescent bulbs, along with various forms of flood and tower lighting, emerged in tandem with increasingly frantic corporate manoeuvring. In the United States, for example, an emerging duopoly between General Electric and Westinghouse sought to prevent other competitors from entering the market whilst a parallel dominance of Osram and Philips marked the European arena (see Nye 1990). These attempts to protect corporate power reached their acme with a meeting held in Geneva in 1924 between the world's leading light bulb manufacturers, including General Electric (represented by a British subsidiary), Osram, the Dutch-based Philips, France's Compagnie

des Lampes, Hungary's Tungsram, and Japan's Tokyo Electric, where the Phoebus cartel was established. This was the first fully global cartel that would dominate the world market for lighting fixtures until 1940 (its planned operation until 1955 was disrupted by war). The cartel succeeded in maximizing the price of its products, dividing up global manufacturing into specific zones (with quotas), and introducing what came to be known as "planned obsolescence" through the design of light bulbs that would "reliably fail" after a specified period of time. In terms of product development, the historian Markus Krajewski shows how the "cartel took its business of shortening the lifetime of bulbs every bit as seriously as earlier researchers had approached their job of lengthening it" (Krajewski 2014b, 3).

The operation of the Phoebus cartel, and its postwar successors such as the Internationale Glühlampen Preisvereinigung, holds significant parallels with the contemporary shift toward LED technologies (widely referred to as "solid state lighting" in the technical literature) (see Krajewski 2014a). The rise of LEDs has been compared with the early twentieth-century transition from gas to electricity, and in particular to the introduction of incandescent light bulbs (see Castro, Jara, and Skarmeta 2013). Although the production of LEDs began in 1962, and was initially quite restricted in its scope, there has been a sharp acceleration in technological innovation since the early 1990s. The contemporary transition involves a new generation of technologies that are more powerful, more energy efficient, and more amenable to external control, thereby providing an implicit segue toward various types of low-carbon "smart city" type discourses. LEDs have been enlisted into the rhetoric of sustainability through new terminologies such as "smart lighting," "smart object alliances," and so on (see, for example, Schubert and Kim 2005; Sánchez et al. 2013). The Flemish region of Belgium, for instance, has begun to replace its existing control systems for street lighting with new forms of "integrated public space management" that extend across a range of technological networks.[11] For Nona Schulte-Römer (2015b, 82), the advent of LEDs marks "a shift from electric to electronic lighting" associated with the rise of "adaptive control systems" as part of a wider nanotechnological transition toward what she terms "solid-state electroluminescence."

Yet the promotion of LED luminaires as an integral component of more environmentally sustainable approaches to urban infrastructure is highly ambiguous because their introduction facilitates the development of more energy-efficient sources of light pollution. Furthermore, the increasing emphasis of LED technologies on the blue wavelength (430–505 nanometers) to produce brighter lamps is precisely the most damaging part of the visible spectrum for nocturnal organisms, circadian rhythms (including human sleep disturbance), and the occlusion of the night sky (see Pawson and Bader 2014). The evolution of LED technologies since the early 1960s has involved a widening colour spectrum from red, orange, yellow, and green toward the eventual achievement of blue in 1993, with a widening range of potential applications (see Schulte-Römer 2015b; Meier 2016). The steady shift from niche markets such as traffic lights to mass usage is generating a seemingly unstoppable surge in the use of LED luminaires for outdoor lighting, supported by a range of influential policy forums, regulatory agencies, and the lighting industry itself (see de Almeida et al. 2013, 4; European Union 2013). By one estimate the complete replacement of high-pressure sodium lamps by LED lighting in Europe, as is now underway with the enthusiastic support of the European Union, could lead to a doubling in current levels of light pollution (Falchi et al. 2016a; see Figure 3). Historical precedents suggest that the cheaper and more efficient sources of lighting provided by LEDs could lead to a dramatic increase in light consumption comparable with past moments of sociotechnical transition (see Fouquet and Pearson 2006).

There has been intense competition between LED manufacturers since the 1990s, leading to the eventual reassertion of dominance by the existing major players in light production that had emerged in the early twentieth century: by 2011 more than 80 percent of the market for LEDs was controlled by Philips, Osram, and General Electric, or their subsidiaries (see Sanderson et al. 2008; de Almeida et al. 2013). In terms of research and development, existing strengths in Europe, Japan, and the United States now extend to new foci in China, South Korea, and Taiwan. Given the sheer scale of the global market for lighting technologies—growing from $52 billion in 1997 to $110 billion in 2011 and a projected $165 billion by 2019—it is unsurprising that the European Union, the United States, and other states have taken such a close strategic interest in this burgeoning sector that has flourished despite recent perturbations in the global economy (de Almeida et al. 2013; Jackson 2016). Global production uncertainties for LEDs are not in any case related to limited demand but to potential

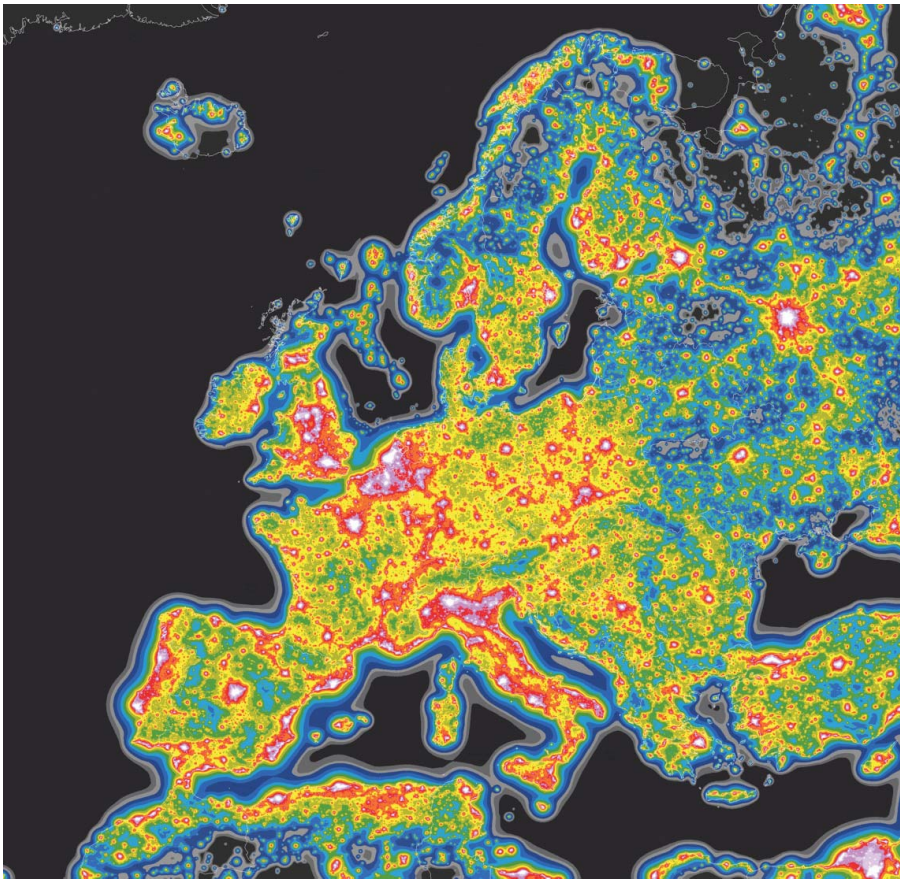

Figure 3. A cartographic representation of the perceived sky brightness for dark-adapted human vision after a transition toward 4000K CCT light-emitting diode (LED) lighting technologies. *Source*: Falchi et al. (2016a, 2016b). (Colour figure available online.)

supply-side constraints for the seventeen rare-earth elements such as cerium (Ce), yttrium (Y), and europium (Eu) used for the coating of phosphors to generate specific colours. Almost all known deposits for these rare-earth elements lie in China and long-standing export quotas were only dropped in 2015 after intense lobbying by the World Trade Organization (see Hornby 2015). Rare-earth elements have become an essential component of "digital capitalism" through their role in the production of not only LEDs, but also lasers, fibre optics, and many other visual technologies.

The seemingly inexorable rise of LED technologies—pivotal to contemporary concerns with light pollution—reveals how citizens are effectively "voiceless" in relation to the future technological pathways for urban lighting.[12] Indeed, the advent of LEDs marks an unusual juncture in the politics of light because heightened public awareness has most often been associated with "blackouts" and various types of infrastructure failure. Both municipal authorities and energy utilities are enmeshed in techno-corporate pathways through their reliance on equipment and expertise. The impending paradigm switch to LED technologies exemplifies a form of autonomous governmentality marked by a remarkable degree of corporate continuity and lack of political scrutiny. Even if municipal authorities want to provide more environmentally sensitive forms of street lighting, they often lack the knowledge or resources to do so (see Krause 2015).[13]

The question of lighting choice rests on the interplay among different interests, circumstances, and constellations of power. Beyond specific material manifestations of light, however, lies the discursive framing of different models of modernity and the degree of choice that can be directed toward particular technological pathways.[14] For Andrew Feenberg, it is the nature of agency—its disposition, engagement, and potential efficacy—that is central to technological politics. The problem lies not in the innate characteristics of LEDs, or other technologies, but in their

application and design. "The poverty of the actual technoculture," as Feenberg (2003, 102) argues, "must be traced not to the essence of technology, but to other dimensions of our society, such as the economic forces that dominate technical development, design, and the media." There is a global stratigraphy to the rise of "digital capitalism" that underpins the shifting cultural and material parameters of new infrastructure systems (see Bratton 2015; Parikka 2015). If we conceive of the "neo-liberal night" as a combination of changing subjectivities and global materialities (see Shaw 2015) this serves as an apposite lens through which to observe the rise of LEDs as the outcome of a series of articulations between local particularities and wider structural developments, including the environmental externalities involved in their production (see Li et al. 2013). The efflorescence of digital media, including the latest generation of LED luminaires, is connected to more distant landscapes of extraction and disposal at a global scale (see Figure 4).

Policy responses to light pollution exemplify what the political scientist Maarten Hajer (2003) terms an "institutional void" (175) marked by unclear rules or normative standards. This apparent policy void has emerged from an increasing dispersal of expertise in the context of weakening state power.[15] We encounter starkly variegated regulatory landscapes ranging from small-scale techno-bureaucratic dimensions to urban design to the emergence of vast "technoscapes" that elude any form of critical scrutiny. Light technologies illustrate what Feenberg (1999, 220) terms "secondary instrumentations," where the intersections between technology, society, and material spaces generate new sets of uncertainties beyond more narrowly essentialist readings of sociotechnical relations. As Wiebe Bijker (1992) shows in his study of fluorescent lighting, this was a technology moulded as much by the social and historical context of its diffusion, than by any innate technical parameters. Similarly, with the rise of LEDs, we have an emerging technological nexus that is being simultaneously shaped by geopolitical dimensions to trade negotiations, corporate power dynamics, strategic state interventions in the fields of research and development, and local sites of policy experimentation.[16]

Figure 4. The heavily polluted city of Baotou in inner Mongolia, northern China (2010). Half of the world's supply of rare earths used in the manufacture of light-emitting diodes (LEDs) is extracted from the region. *Source*: Doug Kantor for the *New York Times*. (Colour figure available online.)

Mood Indigo

We now turn to contrasting cultures of light and darkness. How has the meaning of urban darkness changed? What alternate dystopias have been envisioned in the face of too little or too much light? As recently as the mid-nineteenth century most towns and cities at night were characterized by their relative stillness and darkness. Streets without lighting would have been much darker than any unlit space "under the glowing sky of a modern metropolis" (Baldwin 2012, 10). Even though New York's Broadway was lit with gaslight from the 1820s onward, for example, the city's side streets were described by George Lippard in 1854 as being as "dark as grave vaults" (cited in Baldwin 2012, 16). The uneven diffusion of new lighting networks accentuated existing sociospatial disparities: in late nineteenth-century Washington, for instance, the recently completed gaslight network was concentrated in affluent areas, whereas streets in predominantly African-American districts were reliant on oil lamps or had no lighting at all (Baldwin 2003). Similarly, the working-class districts of industrial cities were poorly lit during the first phase of gaslight installation, with stark differences between elite forms of lighting and more generalized lighting for the purposes of social control (see Bouman 1987).

Street lighting emerged in tandem with the creation of early police forces as part of the organizational and technological telos of the modern state (see Denys 2006). The use of light to impose greater control over space led to bouts of "lantern smashing" in many European cities, especially during periods of social unrest or revolutionary upheaval, because the development of lighting networks served as a visible manifestation of burgeoning state power (and the punishments for these acts of defiance were correspondingly severe) (see Schivelbusch [1983] 1988). With the steady growth of cities, however, the practical and logistical needs for lighting grew, and symbolic associations began to shift toward the more pervasive cultural and functional dimensions to modernity (see Kern 1983; Burckhardt 1989).

The transformation of the nocturnal realm accentuated and unsettled sociospatial distinctions. With the decline of the unruly night of the early modern era a new emphasis on urbanity involved the systematic exclusion of "alternate publics" (Koslofsky 2011, 280). In eighteenth-century New York, for example, a series of "lantern laws" were passed to inhibit the movement of unaccompanied slaves through the streets after dark, thereby identifying "black, mixed-race, and indigenous people as security risks" because their appearance could no longer be concealed by darkness (Browne 2015, 78). The urban night became inculcated into a nascent "bourgeois public sphere" based on systematic exclusions and differentiations (see Koslofsky 2011, 17; Nativel 2016). The early modern fear of the night was reworked in a modern metropolitan context. The history of urban blackouts, for instance, has been consistently charged with racialized or class-based fears of social disorder (notably during the New York blackout of 13–14 July 1977). The blackout phenomenon illustrates an enhanced technological vulnerability under modernity; a momentary glimpse of interconnections engendered by their absence or failure. The blackout, and its multiple sociotechnical entanglements, has also served as a pretext for neo-vitalist insights into the complexity of agency beyond human intentionality (see Bennett 2005). Yet the implicit expansion of agency, and in particular a form of enhanced autopoiesis or posthuman sentience, only provides a partial glimpse of the historical dynamics of light as a focus of cultural and political anxiety.

The politics of light is enmeshed in a powerful security nexus that permeates contemporary urban discourse since fear of crime has long been used in marketing strategies for new lighting products by manufacturers and trade organizations. Yet the relationship between light and personal safety is complex, relating to questions of contrast, patterns of illumination, and the social or cultural milieu within which lighting is used. The stark juxtaposition of light and dark zones, for example, can increase levels of risk or vulnerability, yet the political dynamics of fear militate against reduced or better quality lighting (see, for example, Morris 2011). One of the most comprehensive longitudinal studies undertaken into the effects of brighter lighting found no evidence "to support the hypothesis that improved street lighting reduces reported crime" (Atkins, Husain, and Storey 1991, viii). The history of cities reveals long-standing differences between the incidence and perception of crime as part of a "grid of suspicion" that permeates the urban night (see Cabantous 2009).

An emphasis on quantitative dimensions to light fails to acknowledge the more subtle variations derived from colour, glow, warmth, and other perceived differences (see Bille and Sørensen 2007; Schulte-Römer 2015a). Similarly, the aesthetic dimensions to light-related disputes may pit "bourgeois taste makers," with their demands for "non-blinking" lights and other less

showy forms of ornamentation, against alternative vernacular cultures of light (see Edensor and Millington 2009). In terms of opposition to light pollution, and to certain types of lighting, we find particular antipathy toward brighter types of LED luminaires being introduced in northern Europe. The cultural dimensions to the politics of light include the protection of distinctive "urban atmospheres" such as the gaslight networks of Berlin or the intricate neon scenography of Hong Kong (see Castán Broto 2015; Hasenöhrl 2015). These light-based political constellations are oriented toward the protection of the aesthetic particularities of place against the perceived intrusion of more ubiquitous forms of global modernity. There is a perceived tension between more "authentic" and heterogeneous forms of lighting used in the past and the apparent "inauthenticity" of more homogeneous technologies of the future that have been masked in some cases by forms of technological pastiche such as LED luminaires engineered to resemble non-LED light sources.

We can uncover a series of counternarratives to successive technological transitions spanning early opposition to the use of artificial light in the gaslight era, the favouring of softer gaslights over harsher electric lamps in the late nineteenth century, emerging anxieties over the "aesthetic excess" of the early twentieth-century "electropolis," and more recent attempts to resist the seemingly inescapable parameters of the digital visual realm. For the Japanese author Jun'ichirō Tanizaki ([1933] 2001), writing in the early 1930s, the indiscriminate use of electric light for "dispelling the shadows" (58) instilled his concern with the cultural inauthenticity of brightly lit domestic interiors. Similarly, the German critic Walter Benjamin lamented how gaslights, with their distinctive pale orange radiance, were being displaced by new forms of electric lighting. "With the kindling of electric lights," reflects Benjamin ([1935] 1999, 564) on the changing appearance of the Paris arcades, "the irreproachable glow was extinguished in these galleries." Unlike the "lifeless hardness of electric light," echoes Wolfgang Schivelbusch ([1983] 1988, 153), "Gaslight offered life, warmth and closeness." The affective atmospheres of light intersect with place, memory, and what might be characterised as a kind of "technological nostalgia."

Since the 1980s there has been increasing interest in the role of light within urban design.[17] The cultural geographer Jürgen Hasse offers a phenomenological alternative to existing technical discourses on the affective qualities of light. Hasse's interest in the sensory experience of light, as a component of "urban atmospheres," is rooted in the history of light as a powerful architectural tool (see Hasse 2012). Yet a "reductive" view of urban atmospheres, as the passive outcome of lighting design, restricts the possibility for rethinking human subjectivities (see Edensor 2012; Gandy 2017). There is a presumption that light engineers can shape the way that people feel through the creation of "moods" or "atmospheres" just as environmental design has been linked with narrowly determinist approaches to human behaviour. Although the phenomenological response to light reveals the porous characteristics of affective atmospheres, it is nonetheless ill equipped to explore the material and political complexities of modern lightscapes.

The realm of outside lighting, and in particular the use of illuminated billboards, remains something of a lacuna within urban analysis and design (see Morgan-Taylor 2015). Contemporary concerns with high-intensity LEDs reveal historical parallels with the effects of "glare" from arc lights when first encountered in the late nineteenth century. In North America, for example, the introduction of brighter LED lights has been compared with the impact of construction activity or filming through the night, the harsh lighting of a prison yard, or even the setting for an alien abduction (Chaban 2015). The sense of an emerging LED security nexus, connected with cloud-based sources of information management, is not so far fetched because these brighter forms of lighting are known to facilitate the operation of facial algorithms. If some form of integrated City Management™ were to be installed in urban space, with real-time visual data analysis, then we could expect light to play a vital role.

The increasing ubiquity of LED screens forms part of an aesthetic continuity with earlier types of "billboard landscapes" that first emerged in the 1920s, especially in Southern California, as a visual counterpart to automobile-based forms of mobility (and the need to gain the attention of motorists) (see Wagner 1935). The intersection between architecture and advertising is producing a new generation of urban screens that are larger, brighter, and more dynamic (see McQuire 2008). Light forms an integral part of what Paul Virilio ([1984] 1987, 18) has referred to as the "electronic topology" of the city in which distinctions between architecture, infrastructure, and information are extensively blurred. Los Angeles lies at the epicentre of emerging concerns with more powerful and intrusive forms of illuminated billboards, yet residents with unwanted light spilling into their homes often find to their dismay that these new forms of

signage appear to elude the grasp of regulatory or planning authorities (see Cathcart 2008). Cities as diverse as Chennai, Grenoble, and São Paolo have taken measures to curb unwanted billboards and outsize signage, yet fiscal entanglements trap many municipalities into sponsorship arrangements for the maintenance of their infrastructure systems (see Mahdawi 2015).

Conclusions

Light pollution represents a seemingly intractable dimension to late modernity. The problem evades techno-managerial solutions because incessant illumination is part of the affective realm of global capital. The phenomenon is also a neglected domain within cultural criticism: early responses to brighter lighting such as the somewhat wistful reflections from Benjamin and Tanizaki were preoccupied with the aesthetic and allegorical dimensions to artificial illumination. The more recent emphasis on circadian and ecological disturbances is largely restricted to the biophysical sciences because a political ecology of light has yet to be clearly articulated. Light pollution, as we have seen, comprises a diverse array of elements including the specific characteristics of luminaires, the pathway dependencies of multiple technological networks, and the regulatory voids of late modernity.

The emergence of concomitant public cultures of light should be viewed in the context of a pervasive disconnect between technology and politics. The fundamental paradox facing technological politics, as Feenberg shows, is that technical systems, which lie deeply embedded within state or corporate structures, are often more powerful than democratic processes or institutions. The question for Feenberg (2010), who regards technology, "as *neither* determining nor as neutral" is how we might "challenge the horizon of rationality under which technology is currently designed" (6, 28). It is, after all, only through scientifically enriched forms of "democratic rationalization," to use Feenberg's expression, that technical systems can be disentangled from their existing context and directed toward a wider conception of the common good. Despite Feenberg's compelling critique of technological politics, however, there is nonetheless a sense that his argument cannot be extended too far in the direction of the affective or posthuman realm without risking a degree of disconnect from his underlying defence of Enlightenment rationality. This, then, is the likely point of departure for an emerging theoretical response to light pollution that seeks to engage with posthuman insights or extended conceptions of agency, matter, and the material world.

The presence of urban darkness, like a phantasmogoric manifestation of "weeds," has been characterized as a symbol of disorder, neglect, or abandonment, but there is an intermediate spectrum of illumination that lies between a disorientating gloom and the incessant glare of late modernity. The term *l'éblouissement*—meaning "glare" or "dazzle"—that Lefebvre deploys in his delineation of urban space from the window of an airplane discloses the somewhat fleeting engagement with the complexities of light that has suffused much critical writing about urban space. If we turn our attention to urban stargazers peering in vain to catch a glimpse of celestial phenomena or moths spiraling hopelessly toward streetlights along empty streets we encounter some of the more subtle and pervasive ground-level entanglements of negative luminescence. Light pollution now interfaces with urban space at a variety of scales—from the corporeal level to that of the metropolitan region—so that everyday life corresponds increasingly with the abstract calculations of capital rather than the circadian rhythms of life.

The emergence of light pollution as a focus of concern reflects its own particular dynamics and preoccupations, its intersection with specific fields of expertise, and the wider cultural and political ramifications of artificial illumination. The recent staging of so-called greenouts, with temporary reductions in energy use, in London, San Francisco, and other cities, marks increasing public interest in energy wastage associated with unnecessary lighting (see Nye 2010). Loss of night sky visibility has led to the emergence of new political alliances between different types of light activists including astronomers and ecologists. The creation of "dark sky parks," for example, first established in the Torrance Barrens of southern Ontario in 1999, holds similarities with the setting aside of land for nature reserves and other types of protective "islands." Writing for the Royal Astronomical Society of Canada the astronomer Michael Silver writes:

> At the Torrance Barrens, the ancient constellations and planets shine forth in majestic profusion. On occasion, the northern lights (aurora borealis) are visible—often as greenish wisps but sometimes as spectacular curtains of colour. In binoculars, rivers of stars that are completely invisible to the naked eye flow into view. Rich star clusters, wispy nebulas, the cloud banks of Jupiter and the rings of Saturn are all visible with a beginner's telescope.[18]

The creation of dark sky parks holds parallels with the politics of silence and the protection of spaces dominated by "natural" soundscapes such as the "one square inch of silence" project created in the Hoh Rainforest in Washington's Olympic National Park. There are now thirty-seven dark sky parks worldwide including, in 2015, the first to be opened in South Korea, called the Yeongyang Firefly Eco Park, which evokes more than a symbolic reference to fireflies since the ecology of the 개똥벌레 (gae-ttong-beol-le) is dependent on darkness.

The very ubiquity of light gives it a collective allure that masks its historical specificity and political contingency. The politics of light is entangled with wider zones of cultural and technological contestation, including contemporary attempts to extend the deliberative scope of the public realm. The problem of excess light reveals a series of tensions and incongruities within contemporary environmental discourse including the interrelated threats of climate change and biodiversity loss. The transition to LED technologies, for instance, illustrates a divergence between technologically infused environmental rhetoric and science-based ecological discourse because the emerging political momentum to reduce light pollution is being offset by a new generation of energy-efficient technologies that could facilitate an upsurge in levels of artificial light.

The appropriation of light within emerging sociotechnological paradigms of algorithmic space, as part of the anticipated cloud-based urbanism of the future, tends to overlook the sophistication of past cultures of light. Before the advent of modern lighting many cities varied available light sources in relation to lunar phases and seasonal differences. The human eye was better accustomed to the sensory and navigational challenge of the night with greater mobility under the full moon. We find that contemporary expectations are very different to those of the past: in the 1850s, for example, the mayor of the German city of Bochum had railed against the "absurd modernism" of having gaslights switched on under a full moon (cited in Bouman 1987, 21).

Where they do occur, declining levels of light pollution are usually due to lack of renovation, deindustrialization, fiscal retrenchment, or even deliberate destruction of infrastructure networks rather than any conscious strategy (see Agnew et al. 2008). In the case of Slovakia, for example, satellite imagery reveals falling levels of light pollution since the late 1990s due to extensive closure of industrial installations under the postsocialist transition (Bennie et al. 2014). Although some local administrations—especially within Europe—have sought to reduce levels of light pollution, these are exceptions within a vast and steadily brightening hinterland.[19]

If we try to place the growth of light pollution in its historical context we are faced with difficulties. Are we contending with just a new order of magnitude or with a different set of structural relationships? Do the remarkable continuities in corporate control of lighting presage a technological exception or merely a matter of degree? By reconsidering what we think we know about the past, and developing new insights, we can begin to open up different perspectives on sociotechnological transitions and the development of infrastructure networks. The example of light pollution contributes to a reading of modernity as episodic, multifaceted, and highly contradictory.

In an influential early contribution to the study of light the sociologist Murray Melbin likened the modern night to a time-based "frontier" analogous to earlier waves of "geographic expansion" (Melbin 1978, 3). Yet Melbin's spatial metaphor for the emergence of nocturnal modernity remains only partially developed. The technological transformation of the night is an integral component of the material denudation of the earth.[20] Light pollution provides a striking visible manifestation of metabolic rift at a global scale where the brutality of whale oil production to sustain earlier forms of lighting has been superseded by more pervasive and sinister forms of violence driven by the intersections between fossil fuel consumption, global capital, and a technological modernity gone awry.

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Notes

1. Lefebvre ([1970] 2003, 118).
2. Chamoiseau (2011, 7, my translation).
3. A lumen is the standard measuring unit for light or "luminous flux" and one megalumen is equivalent to 1×10^6 lumen hours. By the early twenty-first century around 19 percent of world electricity production was being used for the provision of lighting (with electricity in turn making up 8 percent of global primary energy usage) (de Almeida et al. 2013).
4. The decisive contribution is undoubtedly Schivelbusch ([1983] 1988), but other influential sources on the nocturnal realm of modernity during this first wave of scholarship include Cauquelin (1977), Melbin (1978), and Schlör (1991). The recent upsurge of interest in the study of light has been marked by theme issues of journals such as *Cultural Geographies*, *Urban Studies*, and *The Philosophical Transactions of the Royal Society*.
5. The most widely used global measure for light pollution is "zenith artificial night sky brightness at sea level" (see Cinzano 2000, 689). Other useful measures include the nine-point Bortle dark-sky scale for the visibility of celestial objects (see Bogard 2013).
6. At the Paris Exposition of 1889 the architect Jules Bourdais proposed to illuminate the whole of Paris with arc lights from a single vantage point (the design competition was won by Gustave Eiffel) (see Schivelbusch [1983] 1988, 3).
7. The use of light as a weapon has been further advanced through the development of lasers to dazzle or even permanently blind enemy combatants.
8. Anonymous. 1887. Liberty's light a lure to death. *Frank Leslie's Illustrated Newspaper* 15 October 1887. The problem significantly worsened after the Statue of Liberty's flame was brightened to serve as a lighthouse. Illuminated skyscrapers located on migratory routes for birds continue to have devastating effects (see Smith 2009; Brox 2010).
9. Circadian photoreceptors have been present in the retinal cells of vertebrates for at least 500 million years (see Hölker et al. 2010).
10. The term "the Great Acceleration" was first deployed at a workshop held in Dahlem in 2005, and is derived from the title of Karl Polanyi's book *The Great Transformation* published in 1944 (see McNeil and Engelke 2014, 213).
11. Traffic Technology Today. 2015. Belgium's Flemish region to deploy "smart" highway lighting system. 14 April 2015. www.traffictechnologytoday.com (last accessed 30 July 2016). For critical perspectives on technological transitions and "smart urbanism" see Marvin, Luque-Ayala, and McFarlane (2015).
12. There are some signs of an international challenge to the power of light producers now emerging with organizations such as the Lighting Urban Community International (LUCI), Guerrilla Lighting, and other groups.
13. Opposition toward LEDs and other luminaires has been partially circumvented through various pilot studies (Schulte-Römer 2015b), the use of "stealth trials" (Shaw 2014, 2235), and other experimental initiatives.
14. On alternate technological pathways, see, for example, Lawhon and Murphy (2011) and Moss (2016).
15. Most existing legislation in relation to light pollution is ineffective, inconsistent, or outmoded. In the case of the United Kingdom, for instance, the so-called nuisance laws that have been intermittently used in relation to light pollution emerged in response to the environmental conditions of nineteenth-century industrial cities.
16. On the emerging field of experimental urbanism see, for example, Karvonen and van Heur (2014).
17. Examples include new kinds of visual experience that transcend existing legal and logistical parameters of public lighting (see Deleuil and Toussant 2000; Edensor 2015). The recent interest in preparing "lighting master plans" marks an emerging facet to techno-modernity dating from the late 1980s with Lyon, Caen, and other French cities emphasizing the concept of *urbanisme lumière* (see Narboni 2016).
18. Silver, M. 2011. The dark-sky experience. Essay published on the website of the Royal Astronomical Society of Canada (3 May 2011). http://www.rasc.ca/torrance-barrens-dark-sky-preserve (last accessed 12 August 2016).
19. A French law introduced in 2013 has enabled whole districts to switch off lights at night to save money and enjoy the night sky. A more comprehensive approach adopted by Slovenia in 2007 explicitly includes the ecological impact of light pollution.
20. I derive this sense of a violent continuity between whaling and contemporary energy extraction from a review of Ian McGuire's novel *The North Water* (see Jones 2016).

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