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Consider the Darkness

From an Environmental and Sociotechnical Controversy to Innovation in Urban Lighting

Samuel Challéat, Dany Lapostolle and Rémi Bénos

Introduction

- 1 Kitt Peak, Arizona, USA, 1972. The professional astronomers of the Kitt Peak National Observatory sought to protect the starry sky and contributed to the regulation of public lighting of the neighbouring city of Tucson. Like many North American cities, Tucson has experienced rapid morphological changes since the mid-twentieth century. The massive development of automobility, urban sprawl, and low production costs of electricity generated the installation of increasingly powerful street lighting, increasing the size and the intensity of the light halo and of sky glow. For the first time, the astronomers from the Kitt Peak Observatory observed light as a problem. The idea of “light pollution” then emerged and began to spread.
- 2 In 1976, the International Astronomical Union meeting in Grenoble Congress passed a resolution for the protection of astronomical sites. A collaboration with the International Commission on Illumination in 1980 led to practical recommendations to reduce sky glow near the observatories. Amateur astronomers entered the dance locally and relayed these professional concerns. In 1993, they united around the drafting of a charter for the preservation of the night environment. This mobilisation resulted, particularly in France, in the creation of a Center for the Protection of the Night Sky, which became, the National Association for the Protection of the Night Sky in 1998.
- 3 Ecologists and physicians have shown the disruptive effects of artificial light on behaviour and biological rhythms. Prior to institutionalisation of this problem by law, some local authorities, concerned with energy saving and environmental image, “tinkered” with their lighting plans. Lighting manufacturers incorporated these issues and provided more efficient public lighting. Finally, some lighting designers welcomed the rediscovery of a dark side in urban lighting.

- 4 Yet, behind these convergences, there remain conflicting interpretations on the actual impacts of artificial light: “light pollution” or “nuisance”? The choice of terms determines the extent of controversy (Alkrich et al. 2003). In everyday language, nuisance refers to the idea of disadvantages, which are small, but nonetheless are a source of embarrassment, without a real or measured impact on health. Indeed, nuisances are difficult to measure, because they depend in part on a subjective assessment by the person who is exposed to them. Nuisances are not standardised unlike pollution.
- 5 The dictionary of the environment of the French Association for Standardisation (AFNOR) defines a pollutant “as a biological “*altéragène*”, physical or chemical, that beyond a certain threshold, and sometimes under certain conditions (potentiation), develops a negative impact on all or part of an ecosystem or environment in general. In other words, pollution is established and standardised by indicators on its causes and effects.
- 6 On the one hand, “environmentalists”, proponents of a comprehensive approach of “nocturnity”, define artificial light as “*altéragène*” of a natural asset – the black – and as a pollutant. On the other hand, “technicists”, supporters of a segmented approach, qualify nuisance issues as raised by artificial light. This is the relation of each to scientific knowledge – currently imperfect in terms of health effects, for example – which is remarkable. For environmentalists, the scientific evidence accumulated by ecologists and doctors is sufficient for decision making (the precautionary principle). For technicists, the same scientific knowledge is too uncertain to be a base for decision. This strategic use of current scientific knowledge must be seen in the trials that take place during the standardisation process. Even if they take place on different scenes, they are structured by the antagonism between technicists and environmentalists. Negotiations determine what should be or not be considered by law and technical standards. For technicists, this is what is measurable and verifiable; for environmentalists, what could happen.
- 7 This confrontation, which is schematically presented, allows, for a theory-based actor-network approach, to understand the logic of actions that shape the sociotechnical controversies surrounding the light “pollution/nuisance”. These “*go far beyond technical issues. One of their challenges is [...] to make a clear and widely accepted boundary between what is considered unquestionably technical and what is indisputably recognized as social. [...] Recognizing its social dimension, gives it a chance to [folder] to be discussed in the political arena*” (Callon et al. 2001). In other words, we must go beyond the technical component of lighting to reach its broader dimension of social innovation (Hillier et al. 2004). According to the definition of the Higher Council for the Social and Solidarity Economy (CSESS): “Social innovation develops new responses to new social needs or poorly met in the current market conditions and social policy, involving the participation and cooperation of stakeholders, including users”. For us, it includes institutional, political, and cognitive changes in favour of a pluralisation of policymaking.

Problematic

- 8 Understanding the social dimension of innovation requires the analysis of sociotechnical controversies, their publicising, and their circulation in the time and network space to anchor in an area under a project approach. We want to show how the scope of the night sky protection problem changes over time at different spatial scales, by expanding coalitions to new actors and objects (Gerston 2004). The combination of these elements is a “window of political opportunity” (Kingdon 1984) leading to institutional decisions. In

the French case, the setting of the political agenda of this sociotechnical controversy questions the mediation and territorialisation logics of the problem, as well as the kind of resources used by the actors. In other words, we explore in these controversies the social relations that underlie the construction of space, i.e. how space produces social innovation and norms that regulate its uses.

Method and empirical material

- 9 To show the spatial dimensions of the social innovation, the analysis crosschecked a variety of sources. Interviews and participant observation were supplemented by the use of private archives, grey literature, and the comparison of each side's stock answers to the salient questions that determine the issues of controversy. The study of the creation and circulation of objects (such as the mapping of light emissions), and of national and international standards informs on the alliance, actors filtering, and problem qualification. The actor-network method is used to define the mechanisms, which set the identity of the actors, their roles, and the topics they cover. We focus on the nodal actors at the intersection of several fields – science, politics, and associations. Because of the technicization of the environmental problems (Comby 2015) these actors are strategic.
- 10 The development of arguments and the flow of ideas, maps, and scientific studies, via interactive web portals, create spaces, and transnational networks that enrich and transform the notion of nuisance value. This notion becomes a framework, a container for environmental controversies whose contents are renewed with the expansion of advocacy coalitions and power asymmetries that structure them. The study of the connections between spaces and actors including different types of mediation may help to explain why night lighting is sometimes termed a nuisance, and sometimes called light pollution. It is an analysing framework of the relationship between social innovation and space (De Bresson et Amese, 1991; Holbrook et Wolfe, 2002; Tremblay et al., 2003).
- 11 This paper is divided into three sections. Section one analyses the emergence and spread of the controversies related to urban lighting. Section two shows the transition from conflictuality to participation, while section three focuses on the multi-scalar dimension of the interactions between space and norms, and their social and spatial innovative dimensions.

From urban lighting to light pollution fighting

French politics innovate by a decentralized and participative method

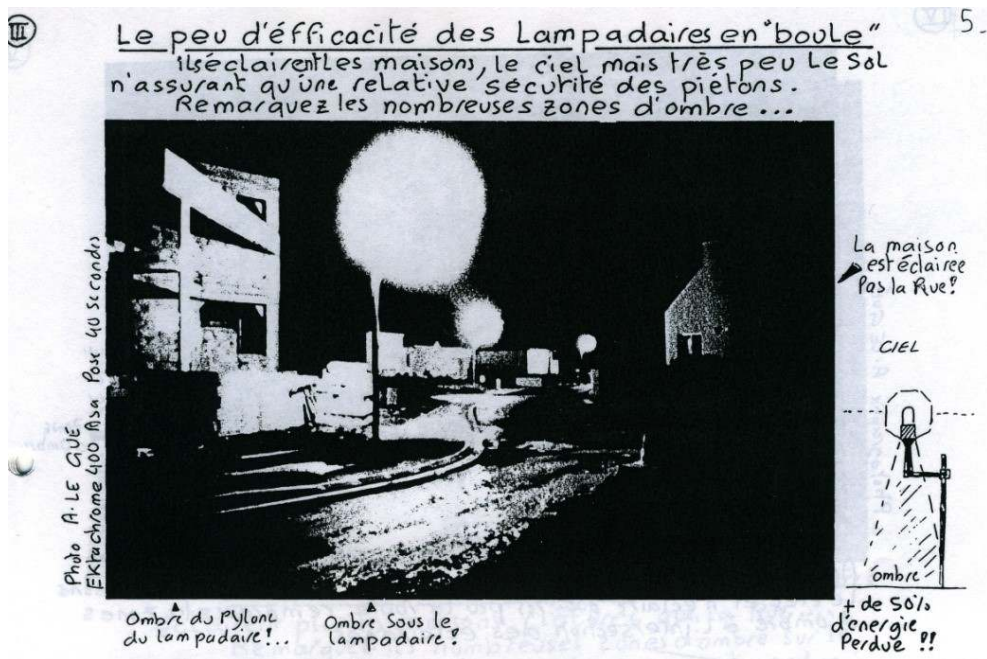
- 12 In 1982, Michel Crépeau, Minister of the Environment, launched the “*États régionaux de l’environnement*”. As part of the newly established local government, association activists were invited to develop a Charter for the Environment. The political objective was a watershed in the development of public policy. The region, through its planning mission, builds its legitimacy through the enrollment of associations. The claimed approach is decentralized and participative. This pluralisation of policymaking is a kind of social innovation, which provides associations with the possibility of managing natural resources and areas by contracts. Seizing this political opportunity, astronomical amateur associations come into play: they integrate the “*Secrétariats des États régionaux de l’environnement*” responsible for the drafting of a white paper. They claim the protection

of the dark sky by placing their members in key positions. For example, in Burgundy, Jean Claude Merlin – president of the Astronomical Society of Burgundy, laureate in 1982 of the Bleustein Blanchet Foundation for Vocation, creator of an astronomical observatory at Le Creusot and discoverer of comets – became correspondent of the *États régionaux de l'environnement* for this territory.

The transnational networking of the astronomers

- 13 This participative policy failed, but it does not mean there is futility (Hirschman 1991) with this kind of collective action. This public action opening was an opportunity for amateur astronomer associations to publicise their claims, to pave way for expertise and build a national network, whose actions crystallized in 1993 with the drafting of a “Charter for the preservation of the night-time environment”. This charter was supported by some media-scientific figures, such as Jacques Yves Cousteau, Albert Jacquard, and Hubert Reeves.
- 14 It made practical recommendations in the fields of urban planning, goods, and people security, saving energy and their governance. In October 1995, a congress took place at Rodez, which strengthened this approach and led to the creation of an associative committee open to institutions, such as the “*Agence de l'Environnement et de la Maîtrise de l'Energie*” (ADEME), “*Electricité de France*” (EDF) and the “*Association Française de l'Eclairage*” (AFE). The enlargement of this coalition goes along with the diversity of tinkered objects intended to publicise the problem. The tinkered objects include manuscripts tracts, amateur photographs, maps of these new forms of pollution that are not recognized by the public authorities, arguments, and technical drawings for elected representatives (Fig. 1).

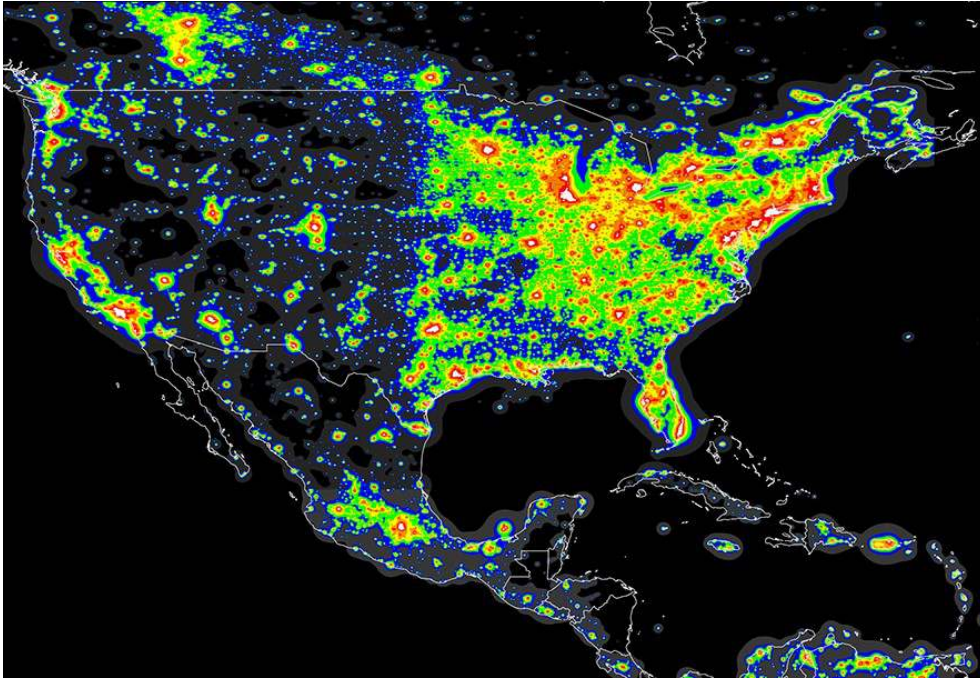
Fig. 1. Extract from awareness materials produced by the defenders of the night.



1994, ARCHIVES OF THE ASTRONOMICAL SOCIETY OF BURGUNDY, DIJON

- 15 In 1998, a second conference was held in Rodez. As a result, the “Association Nationale pour la Protection du Ciel Nocturne” (ANPCN) was created with the following objectives: “restore and protect the quality of the night sky and educate stakeholders in order to adopt appropriate measures at national and international levels”. The ANPCN was immediately enrolled in an internationalization strategy by joining the International Dark-Sky Association (IDA). This was founded in 1988, on the initiative of David L. Crawford, an astronomer from Kitt Peak, who was a key player in the agreement on the regulation of Tucson lighting. The IDA has built a recognised expertise enabling it to have today a “Public Policy and Government Affairs office” in Washington DC. The IDA, after the “Dark-sky movement”, constituted a corpus of amateur and scientific works and technical recommendations that are resources for other less structured national associations. It has diffused its method of participatory expertise to defend the night. This expertise is understood as a cognitive resource mobilised by different actors who act according to plural motives (Dumoulin et al. 2005) in response to uncertain situations (Trépos 1996). Combining the vernacular and amateur knowledge, this expertise infuses the production of scientific and institutional knowledge that maintains and advertises the controversy.
- 16 This production of new scientific knowledge is validated through the usual channels of peer-reviewed publications, which legitimizes this participatory expertise. The issues of expertise independence and science politicization are relegated to the background (Memmi 1989; Saint Martin 2006). In 2001, Cinzano *et al.* wrote a reference paper, *The first World Atlas of the artificial night sky brightness* (Cinzano et al. 2001), which shows that “assuming average eye functionality, about one-fifth of the world population, more than two-thirds of the United States population and more than one half of the European Union population have already lost naked eye visibility of the Milky Way.” (Cinzano et al. 2001). The dark-sky movement has used this new scientific knowledge to produce an iconography of light pollution, which will be completed by satellite images of “Earth at night” widely disseminated to the general public (Fig. 2).

Fig. 2. Cartography extract from The first World Atlas of the artificial night sky brightness (Cinzano et al. 2001).



Credit: P. Cinzano, F. Falchi (University of Padova), C. D. Elvidge (NOAA National Geophysical Data Center, Boulder). Copyright Royal Astronomical Society. Reproduced from the Monthly Notices of the RAS by permission of Blackwell Science.

The structuring of new fields of knowledge and action on the nocturnal environment

- 17 Alerted by these impacts on the night sky ecologists emphasise the environmental costs of lighting, by showing ecosystems disturbed by artificial light. On multiple scales, biologists observe many effects on wildlife. On a small scale, these effects are essentially mechanisms of attraction and repulsion by light sources, whereas on a larger scale, these are disorientations by sky glow.
- 18 Many behavioural disturbances are also identified on communities and ecosystems at variable time scales. From the perspective of human health, medical research shows that the natural day/night cycle is the first time coordinator for our internal clock. This exogenous synchronizer regulates circadian secretion of several hormones, including melatonin. Its de-synchronization may cause stress, fatigue, deterioration in the quality of sleep, irritability, and eating disorders. Finally, the quality of circadian rhythmicity of melatonin secretion could slow the onset of certain cancers.
- 19 The convergence of different scientific disciplines leads to scotobiology, defined as the study of biological reactions and behaviour that require darkness for their normal operation (Bidewll 2010). Beyond the scientific value of this work, the scotobiology can be seen in its politicization of the public dimensions. According to Bidwell,
- “There is always difficulty in raising money for the development of ecosystem improvement programs. It is necessary to focus both public and scientific interest on problems for them to be effectively addressed. The public interest in light pollution has already been aroused by problems like bird deaths and by the recent

flowering of interest in dark-sky reserves. [...] This has to be done in ways that attract public interest. If this is done properly, scotobiology will focus more and more effectively on the real consequences of light pollution, and perhaps bring about a revolution in the way our society approaches this global ecological concern. Clearly, without public education, political action will not happen. Our parks can and should provide a focal point and a powerful opportunity for public education and arousal.” (Bidwell 2010).

- 20 The political education of the public is also claimed by Globe at Night. NASA is behind this American educational programme established in 2005, which focuses on school science education. Led by the NOAO (National Optical Astronomy Observatory), it became international in 2009, during the International Year of Astronomy. It builds on an ancient practice of participatory science that finds its relevance in environmental controversies. It can be considered to be an enlightened amateur mobilisation in favour of scientific knowledge production as an end in itself. However, it can also be addressed as the enlightened amateur engagement in the production of public policies about scientific and technical issues and the commitment of researchers in the democratic process (Lewenstein 2004). It is a kind of public action pragmatic regulation (Habermas 1973) that questions the relationship between policymaking, technical, and scientific knowledge. Thus, the “*scientifisation*” of the policy is based on a critical interplay between science and policy. This leads not only to the translation of scientific knowledge into practical knowledge, but also to the streamlining of scientifically political domination by opening it via *ad hoc* procedures to the public. This collaborative repertoire and work outside the laboratory as opposed to confined science (Callon et al. 2001) implemented by Globe at Night, the IDA, or the Association nationale pour la protection du ciel et de l’environnement nocturnes (ANPCEN), may contribute to the advent of a pragmatic regulation. However, it must accommodate established power relationships.

Lighting professionals come into play

- 21 Historically, public lighting is an urban development tool. This excerpt from the “*Code de bonne pratique*” for public lighting and light signalling, edited by EDF in 1958, illustrates:
- “For urban roads, the requirement of efficient lighting is now combined with a pleasant lighting atmosphere [...]. Therefore, the public lighting of an urban area must be a comprehensive plan that integrates the planning program. Major roads carrying heavy traffic must, with gorgeous lighting, draw the backbone of the city [...]. For historical monuments, public parks, beautiful sites, of which the city is justly proud, their development should be particularly careful [...].”
- 22 Behind the aesthetic and sensory attention hides a more functional approach of public lighting. As early as 1930, it was rationalised that it could be applied uniformly in an urban space reduced to a system of traffic and parking. The increase in night traffic in 1960 was consistent with the artificial light intensification along the road. This functionalist approach was accompanied by prescriptions from institutionalised actors. In 1961, AFE published the first *Recommendations for street lighting* (AFE 1961), followed by the first *International recommendations* of the International Commission on Illumination (CIE) in 1965.

Technicians *versus* Environmentalists: the pluralisation of the expertise

- 23 Founded in 1930, the AFE now brings together “more than 1,000 architects, designers, decorators, doctors, researchers, ophthalmologists, city engineers, officials of the road and urban equipment, installers, distributors of electricity, wholesale distributors, manufacturers of lamps, lighting management systems and components” (AFE website). The diversity of its members ensures that this professional association is in an indispensable position in the expertise around light and its standardisation. To relay its action, the AFE uses three levers. Firstly, the regional centres bring their expertise to the municipal technical services. Secondly, in 1928, LUX magazine was founded, and it is still one of the main publications about lighting technology in France. Finally, the AFE regularly publishes recommendations, like Energy efficiency in street lighting and Guide for sports facilities lighting, etc. Reading them exposes the dilemmas that cross the association, because of the multiplicity of its members’ interests, knowledge, and representations. “Right Lighting” is integrating environmental stress in the economic logic of many lighting professionals.

“I start from the premise that the AFE is an association of lighting engineers / people / professionals / lighting professionals who have / who have...er... / in speech marks, the opportunity to make a fortune out of lighting / so I don’t think you can be objective when there’s money at stake [...] it’s difficult to be both judge and jury when all’s said and done / you can’t just say...er...’ we’re cutting back on the lighting’; if they cut back on the lighting then I’m not going to sell any more lighting / ...er... and I think they’re not asking themselves the right questions, in other words we should be saying ‘well, I’m not going to sell any more lighting’ instead of saying ‘that would enable me to renovate a complete installation’ // I think that the the AFE’s problem is that ...er... / they’re not sufficiently ...er... in speech marks, multi-activity; there’ll be manufacturers and lighting engineers but there won’t be anyone from an association, for example” (Interview with an energy syndicate employee, 2009).

“Because I met with the Chairman of the AFE / and I said to them straight: ‘So who’s drawing up the standard?’ He said ‘well, me’, and I said ‘and who are you?’ ‘I’m a manufacturer’ / I said ‘really!’ / I’ve come across this in the drinking water sector, where it was the drinking water plant manufacturers who set the standard, so once you’d found nitrates, great, they found you something else then something else again and you never got to the end of it” (Interview with an energy syndicate director, 2007).

- 24 In 2010, the AFE published the article *Public lighting: Answers to 40 questions too often misguided* in LUX magazine. To the first question: “Can the nuisance of artificial street light be called ‘light pollution?’” The response from the AFE marks their distance from ANPCEN:

“NO – Pollution, when it occurs, simultaneously concerns men, animals and plants, and its treatment should be as long and unique as for treatments for air and water pollution. Light does not pollute, light is invisible; but it can generate multiple and varied problems of which the effects, as far as remedies, are specific and different in each case. When light ceases, its potential nuisances disappear.”

- 25 The ANPCEN reply was contradictory:

“YES – Because, when excess light is sent outside the useful light area, and it exceeds a certain threshold (in terms of flux and spectral composition), it affects the night-time environment via a repulsion or attraction effect to night-time

wildlife (following the species and changing the alternating day/night cycles, with an effect on the flora and sleep in humans via the intrusive light).”

- 26 The differences in approach are conspicuous: The “technicist” approach addresses the problems in terms of nuisances only, and the global “environmentalist” approach designates “pollution” as the impact of artificial light. Beyond the semantic and scientific issues, it is the voice of expertise that is in question, which is evidenced by this excerpt from a publication of the AFE (“*Polémiques sur la norme expérimentale AFNOR: Nuisances lumineuses. Quand l’outrance nuit à la vérité*”, 2011):

“When information does not allow to convince and influence the citizens in the good meaning, some lobby groups do not hesitate to promote disinformation campaigns against unscrupulous accumulating truths, technical errors undetectable by non-specialists, relying on sensitive domains of the moment (environment and energy).”

- 27 Some lighting designers also support the negation of light pollution. One of the most famous in France, Roger Narboni, says in the review *Urbanisme*: “*We try to make city dwellers understand that if there is light pollution in our cities, it is primarily because there is pollution. Because the light is immaterial, it is only seen in the material or elements in suspension.*” (Narboni 2011). This willingness to shift the light pollution towards air pollution is a strategy to avoid the controversy. However, Roger Narboni and some other light designers promote a greater aesthetic sensibility in their approach of the landscape dimension of the night (Narboni 2003; Mosser 2005; Mallet 2011). They are at the intersection of technicist and environmentalist conceptions of public lighting (Edensor 2015). They question the lighting levels used in lighting projects and also re-evaluate the role that darkness plays in lighting.

“I don’t understand how, in twenty years, a busy street can go up from 24 lux per square metre, which is very comfortable and acceptable, to 50. [...] I know that you get more light for the same consumption, but we’ve just forgotten that the result is a light overload. [...] The light has increase n terms of lux intensity and draconian standards are being imposed without any sort of discussion. Light pollution is caused by street lighting and shop windows. The glare from towns and cities is considerable, and it all accumulates into a great cauldron of light. We might have hoped that light could be treated with greater subtlety and sensitivity. [...] No town should look like another one at night. [...] We should be taking a lot of factors into consideration in order to create a different form of light that expresses the “beating heart of the place”. Each town has its own electrocardiogram that we can use to emphasize its own special heartbeat and rhythm.” (Interview with light designer Yann Kersalé in the daily newspaper *La Croix* on 14 November 2011, http://www.la-croix.com/Debats/Opinions/Debats/Les-villes-ont-besoin-de-calme-de-douceur-de-serenite-_NP_-2011-11-04-731765).

- 28 The different positions illustrate the difficulty of defining terms, units of measurement, and quantification of impacts and effects, required to unify the problem and its governance.

Transform and universalize the problem to participate

- 29 From its inception, the ANCPN has been accused of being an emanation of astronomical associations. It changed its name to ANPCEN in 2006, and moved towards a comprehensive defence of the night-time environment. This new orientation allowed it access to the negotiations of the “*Grenelle de l’Environnement*” in 2007. Paul Blu, president of the Association said: “*Our name emphasizes the protection of the dark sky. We need to change*

the name of the association and give it an environmental connotation." Pursuing this strategy, the association, in a "greenwashing" operation, adopted a new logo focused around "*the commitment, the lookout, the protection, the gathering in a setting reminiscent of the danger of our situation (the threats to our night-time environment) and our ability to provide solutions*" (SOS newsletter n° 37).

- 30 In the fall of 2010, Anne-Marie Ducroux replaced Paul Blu as the head of the association. She did not come from the astronomical seraglio. Her professional background in the world of communication and media and her personal involvement in the creation of the "*Conseil National du Développement Durable*" (National Council for Sustainable Development), which she chaired between 2005 and 2006, are relational resources for ANCPEN. She liaises with NGOs and politicians, and her interpersonal skills, law making, and administrative knowledge make her a mediator who will allow the association to remain in the post-game Grenelle. However, it is mainly by joining "*France Nature Environnement*" (FNE) in 2007, that the doors of the Grenelle were opened.
- 31 FNE brings together nearly 3,000 environmental organisations at the national level and summarises the expert report by the associations. It is a fixture in major national environmental consultation commissions. Joining FNE gives the ANCPEN a stronger environmental legitimacy at the national level. Therefore, the protection of the night-time environment found a seat at the Grenelle negotiating table at the end of 2007.
- 32 During the first phase of negotiations, NGOs occupy a prominent place alongside the state, local authorities, employers, and employees. They participate in six working groups, each involving 40 members divided into five colleges. Carried by the FNE, light pollution is integrated into the Grenelle 1 bill of 2008. Article 36 says: "*The emissions of artificial light, likely to present dangers or to cause an excessive disorder with the people, fauna, the flora or the ecosystems, involving an energy wasting or preventing the observation of the night sky, will be the object of preventive, suppression or limitation measures.*" On 23 September 2008, Nathalie Kosciusko-Morizet, Secretary of State for Ecology, brought together in the *Observatoire de Paris-Meudon* various stakeholders interested in light pollution, to carry "*Article 36*" (which became Article 41 in the legislation enacted on August 3, 2009) to the national media:
- "This phenomenon has been ignored for too long, and is now in the bill relating to the Grenelle de Environment, examined in parliament from October. This legislative recognition will create a new chapter in the Code de l'Environnement to regulate the over-lighting. It is the culmination of a long battle for Nathalie Kosciusko-Morizet, Secretary of State for Ecology, who wishes to sensitize the elected representatives and the public to this still not well-known environmental issue." (Press kit on the visit of the Secretary of State for Ecology at the Observatoire de Paris-Meudon, September 23, 2008).
- 33 Through the "long battle", the Secretary of State for Ecology referred to the Proposed Law No. 2275, on the fight against light pollution, which she had proposed to the *Assemblée Nationale* (April 14, 2005) when she was a *députée*. On June 29, 2010, the assembly adopted the bill on national commitment to the environment, so-called "Grenelle 2". Article 173 inscribed the prevention of light pollution in the *Code de l'Environnement*. The Decree of 12 July 2011, created in the regulatory part (Articles R. 583-1 to R. 583-7) a specific chapter for light pollution. It defines the installations concerned, the zonings to adapt requirements to the challenges of the concerned territories (urban or natural areas and astronomical sites), and the main technical rules, which may be regulated by decree. The first application text is signed January 25, 2013. It covers both the interior light

emitted towards the outside of non-residential buildings (storefronts, offices, etc.) and lighting of the facades of these buildings, and it frames the time of operation of these facilities.

- 34 However, this codification remains linked to the production of technical standards. The production of lighting thresholds reveals the permanence of the divide between technical and environmentalist approaches in this controversy.

From the environmental controversy to the territorial implementation

- 35 The spatial dimension of this controversy appears in the standardisation scenes understood as regulation devices. They contain a plurality of trading venues that must be identified to account for them in their entirety. This approach allows us to understand the laws, regulations, and technical standards. Whether they are caught by scenes, different values, and legitimacy are nevertheless related to their regulatory effects (Thévenot 1997). From the European Commission to the village lane, the standardisation scenes of public lighting are traversed by economic, technical, health, or environmental tensions. For example, the industrial and commercial standard AFNOR hardly accords civil and environmental claims. We can observe the same problems in the production of indicators related to a lot of diffuse pollution. The construction of these regulatory tools and discussions to which they are subject, indicate difficulties in reconciling the approaches and methods of the players involved in the development of the tools. They also reveal the power relations in the definition of standards according to the prevailing vision in a professional field (Boutaric 2007). The development of these indicators requires the organisation of consultations among a variety of institutional levels, professions, and interested parties, as well as places where dialogue, controversies, and collaborations can happen. The achieved compromises between technicians and environmentalists lead to zoning. That is a way to segment problems and to treat them with specific standards.
- 36 The spatial spread of the problem by zoning, participates in the standard making process. It confirms some territories and creates others. Conversely, space itself is a standard producer.

The technical standards product spaces

- 37 The experimental standard AFNOR XP X90-013 making under the Grenelle 2 law and the European Directive 2005 optical radiation is underway. Its challenge is to determine light radiation thresholds and indicators to protect biodiversity and human health in public and private spaces. However, it is also to secure trade. This is the reason some economic agents incorporate standardisation activity in their strategy.
- 38 The composition of the standardisation committee relatively reflects the plurality of interests and values (see: http://www2.afnor.org/espace_normalisation/structure.aspx?commid=2404). If only one association for the protection of the environment, ANPCEN is present, the General Labour Directorate and Directorate for the Prevention of Pollution and Risks could help to overcome the purely commercial nature of standardisation. Without prejudging the intentions of the members of the committee, its composition

reflects the permanence of the divide between technical and environmentalist approaches, evidenced by this bittersweet exchange between the AFE and the ANPCEN about the definition of lighting levels. The ANPCEN asks for the possibility to turn off the light with a maximum lighting threshold:

“Especially lax in defining thresholds of lighting installations’ power, this experimental standard contradicts the recommendations of scientists, and international references to limit light pollution. [...] Paradoxically, the chosen method is based on the principle of ‘minimal to maintain’ and not ‘maximum not to exceed’ to limit light pollution. [...] Elliptical, it removes from its scope all aspects of the biological consequences of excessive or inadequate artificial lighting.” (Excerpt from press release of the ANPCEN, June 15, 2011. “L’Association nationale pour la protection du ciel et de l’environnement nocturnes (ANPCEN) appelle au retrait de la norme expérimentale censée ‘minimiser’ les ‘nuisances lumineuses extérieures”).

39 The AFE requires the maintenance of a minimum lighting level:

“We must remember that this is an experimental standard and as such, it can only deal with ‘measurable and verifiable’ issues. Therefore, writing, as does the ANPCEN, that the standard is ‘useless’ because it neglects the effects of light on biodiversity, is inaccurate: unto this day, these effects due to public lighting are not measurable and cannot be integrated in an experimental standard. [...] Public lighting is in full technological changes. Today, we can make energy savings, which regularly exceed 50% of the energy consumed so far. We can modulate the lighting upon request. In France, the production of CO₂ practically does not concern the public lighting, as 85% of it is nuclear powered. Currently, public lighting is not severely affected by peak consumption, as it represents only 2%, and in addition most economies remain to be done.” (“Polémiques sur la norme expérimentale AFNOR” “Nuisances lumineuses”. Quand l’outrance nuit à la vérité”, Le point de vue de l’AFE, n°13 – July 1, 2011).

40 For ANPCEN, scientific evidence accumulated by ecologists and physicians is sufficient for decision making (the precautionary principle) whereas, for AFE, the same scientific knowledge is too uncertain to make a decision. This strategic use of scientific knowledge must be seen in the negotiations that take place during the standardisation process. These negotiations determine what must be taken into account or not, by the law and the technical standards. For technicians, that is which is measurable and verifiable, while for environmentalists, that which might happen.

41 Their reconciliation is done on energy savings in a new zoning: astronomical observation sites are often located in low-density spaces, in terms of population and activities. More generally, light pollution is taken into account in other existing environmental zoning: natural reserves, parks, and heritage sites. Their disagreement is sensitive to urban spaces in which the entanglement of health, environmental, and economic issues is more pronounced. Either, the danger of lighting to human health is recognized, and in this case it is the high-density areas and their inhabitants who are to be protected against light pollution, or the danger of lighting is not proved, and economic interests manifest themselves more directly. It does not mean that the standard is inefficient, but it portrays a risk to human health, which is treated by a specific device for reassuring people.

The spatial scales domesticate and supply the technical standards

42 The characteristics of the listed spaces in the regulatory text (12 July 2011, published in the *Journal Officiel* July 13, 2011) – for example, protected natural areas, urban or non-urban areas – are arguments taken into account in the definition of lighting levels. It

means that local adaptation of lighting standards erects space as a mediator of social relations. As an illustration, the experiment carried in the department of *Saone et Loire* between 2007 and 2009 is instructive.

- 43 The Departmental Union of Energies of *Saône et Loire* (Sydesl), in partnership with the local correspondent of the ANPCEN, the Interdepartmental Directorate of Roads, mayors of concerned rural municipalities, the delegates of “inter-communalities” and the ThéMA research laboratory (University of Burgundy), developed an experimental method for defining public lighting standards, according to different characteristics of the concerned territories. The low density in this predominantly rural area, the presence of remarkable flora and fauna, the landscape amenities, and the sinuosity of county and rural roads are carried by various workshop participants. Thus, each participant is the legitimate custodian of a fraction of the space system. This space system turns into a local adaptation system of the European Standard EN13201. The European standard EN13201, which is non-binding, has been applicable in France since 2005. It gives the minimum illumination levels to be maintained according to the type of road or pedestrian area, and it has been under revision since 2009. Therefore, for each type of road, the illuminance values are defined to correspond to the thresholds of the EN13201 standard.
- 44 In addition, the use of passive forms of signage is encouraged so that, in terms of road safety, public lighting does not distract drivers. A charter accompanies the device. It aims for the standardisation of public lighting in rural municipalities, starting from “natural” zoning (ZNIEFF – *Zone Naturelle d’Intérêt Ecologique, Faunistique et Floristique* – and ZICO – *Zone Importante pour la Conservation des Oiseaux*), and sensitive areas around the sites of astronomical observations. According to the various zoning types, the characteristics of luminaires are determined according to their type. Hours for cut-off of public lighting are recommended, and a system of management of the network, which limits power to certain hours of the night, is proposed to municipalities, which do not want to completely cut-off public lighting in the middle of the night.
- 45 This local adaptation system of the standard is a social innovation that provides practical answers to questions asked by the elected, in terms of security of goods, people, and displacements while incorporating the protection of the environment. This system, negotiated with State Technical Services, has expanded to the neighbouring department of Jura, which incorporated a wider range of participants. Informed of this project the “*chargé de mission Maîtrise de la Demande d’Électricité*” at ADEME relayed this initiative to the national level. This work was presented during a mediated picnic at the *Observatoire de Paris-Meudon* September 23, 2008. While it nourished the controversy during the Grenelle 2 public negotiations, it remains a dead letter at the departmental level, paradoxically reinforcing the role played by space as a social mediator.

Conclusion

- 46 The forty plus years’ study of the course of a sociotechnical controversy through animated scenes by local, national, and transnational networks, shows how social relationships invest and structure space. The controversy features a large number of players – led to create and acquire knowledge – who play the role of experts to contribute to the “Policy and norms making” (Boutaric 2007). In this set of actions, conflicts of interpretation change positions and arguments during the process of qualification of a problem. The state institutionalises this collective action into standards, but the

institutional analysis is insufficient. It does not show the activists and individual logics that expand and change their mobilisation repertoire beyond borders (RENOIR Research Group 2014).

- 47 The “Dark-sky movement”, the IDA, through participatory and educational uses made from scientific productions such as *The first World Atlas of the artificial night sky brightness* or *Globe at Night*, shares methods via social networks that highlight the visible problems. This work is powered by new scientific knowledge. But if this condition is necessary, it is insufficient to ensure visibility of the controversy: the mobilisation relay, whether individuals, groups, objects, or institutions must be at the heart of the analysis of what perpetuates an environmental problem and increases its “moral considerability”, because they cross and structure controversial spaces.
- 48 The analysis follows social innovation logic. Social innovation develops flexible organisational responses, by adding value to goods not considered by the market (access to amenities in the dark), by providing new institutional arrangements involving the participation and cooperation of stakeholders, including users in different spatial scales. (Hillier, Moulaert, Nussbaumer 2004; Klein, Lavoie, Moulaert 2014). Thus, urban lighting cannot be reduced to equipment or consumption of goods. The market framework is too narrow to account for the multiple dimensions of urban lighting related to urban design, ecological concern, or safety and health issues. As it falls on the issue of well being, it is partly reinserted in a spatial logic of social innovation, under tension between utopia and institutionalisation (Blanc 2009).
- 49 The institutional recognition and consolidation of these multiple dimensions has a price to pay: it goes through “normalisation”. Indeed, the spatial spread of the controversy in the zoning and the standardisation process appears as a partial regulatory response to a complex problem, by embedding its social, scientific, and spatial dimensions.

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ABSTRACTS

This article explains the birth of an environmental problem, light pollution, which is understood to be a controversial source of social innovation. Over forty years, in support of the actor-network approach, it traces the conditions of its emergence, transformation, and dissemination to local, national, and transnational levels, and through various professional disciplines. Schematically, “environmentalists” uphold a holistic approach of “nocturnity” and define artificial light as a pollutant. Facing them, the “technicist” defends a segmented approach and defines artificial light as a nuisance. In France, the implementation of this controversy on the political agenda leads to institutional decisions that grasp it with difficulty in all its social, scientific, and spatial dimensions. The spatial spread of the controversy in the zoning and the standardisation process appears as a partial and segmented regulatory response to this problem. However, these processes can be considered to be forms of social and spatial innovations.

INDEX

Keywords: innovation, urban lighting, controversy, light pollution, the night-time environment, lighting regulation.

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