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Unawareness in environmental protection: The case of light pollution from traffic

Abstract

New information is often emphasized as a basis of effective and scientifically sound environmental policy and management. However, outdated or incorrect information is not automatically nor instantly replaced by new insights. This article focuses on the various ways environmental information can be unintentionally left with insufficient attention or purposefully neglected. Energy-related emissions caused by road traffic in Finland are used as an illustrative example and light pollution caused by artificial lighting is identified as an emerging issue that has gained especially low recognition in the environmental agenda. Four different reasons for this lack of recognition are discussed: recognized unawareness, false awareness, deliberate unawareness and concealed awareness. Paying attention to light pollution is important because of various ecological, socio-cultural and economic effects but also because implementing measures aimed for reducing light pollution create possibilities for alleviating other social and environmental problems in transport and land use policies.

Highlights

Light pollution from artificial lighting is a widespread environmental change affecting most areas of industrialized world.

It can have serious ecological, health and economic consequences.

Light pollution has not been recognized as a key environmental problem.

Acknowledging the problem is required in order to decrease the extent and intensity of harmful light pollution.

Keywords

Energy; Environment; Recognition; Risk: Road traffic; Light pollution

Introduction

Prioritization of environmental problems and their potential solutions is a necessary precondition for sustainable development. Identifying, assessing and prioritizing environmental issues is however a difficult task for environmental science and policy. The state of the environment is constantly evolving because of changes in both anthropogenic pressures and natural processes. Surprises can be faced as a result of ecological thresholds (Scheffer and Carpenter, 2003) or social transformations (Loorbach and Rotmans, 2006), including genuinely unexpected events, processes and factors. Scientific studies and monitoring programs do not necessarily produce information on all potentially harmful environmental changes. Even so-called mega-assessments (Toth, 2003), including the Millennium Ecosystem Assessment (MEA, 2005) or the reviews by the Intergovernmental Panel on Climate Change (e.g. IPCC, 2007), are unable to embrace the full variety of environmental problems embedded in diverse socio-ecological systems.

Prioritization is constrained even if the information on environmental states and pressures would be perfect, as there is no unambiguous and universally valid way to rank the issues (Svarstad et al., 2008, Assmuth and Hildén, 2008, Tapio and Willamo, 2008). Their order always depends on the context, on those prioritizing, and on their value judgments in defining the prioritization criteria and principles (Assmuth et al., 2009). Solution priorities in particular depend on such judgments and deliberations that cannot be resolved by science alone (Sarewitz, 2004).

There are even greater problems outside the scientific domain. Only some research results gain visibility in public debates or in policy-making while the vast majority sinks into oblivion without direct, strong or extensive influence on decision-making. Media attention highlights various environmental issues that can be, depending on the criteria, real threats or false alarms (Mazur, 2004, Hannigan, 2006). Socio-economic interests as well as cultural and historical influences can have a much stronger impact on what is considered important than the direct effect of scientific reports or assessments. However, the indirect and mediated impact of science can be important.

Our aim here is to examine and discuss why and how potentially important environmental issues are left with insufficient attention in environmental assessments, debates and decision-making. We use the light emissions and light pollution from traffic in Finland as a case. The example extends the view of the physical space to the energy space, taking into account the human colonization of the dark areas by light. By examining the light pollution discourse and debate (and non-debate) we aim to improve the understanding of which factors are causing potentially relevant scientific information to be intentionally or unintentionally left without sufficient attention, how this happens, and what are the implications of such inattention.

Light energy is an especially interesting case because (i) light is easy to sense even without any technical instruments; (ii) light has profound impacts on humans and other organisms, both biological and socio-cultural (Mizon, 2002, Rich and Longcore, 2006); (iii) only relatively limited attention has been paid to light pollution, compared to many other forms of pollution, even though light emissions have increased rapidly (Cinzano et al., 2001, Narisada and Schreuder, 2004, Chalkias et al., 2006, Smith, 2009, Hölker et al., 2010a); (iv) consequently, the assessment and management of light pollution and associated planning is undeveloped in comparison to efforts to increase lighting (see Gallaway et al., 2010, Falchi et al., 2011).

Our study builds on and combines earlier approaches to emerging environmental issues (Munn et al., 1999, Daughton, 2001, EEA, 2001), weak signals (Mendonça et al., 2004), evolution of environmental coverage of media (Boykoff, 2009, Lyytimäki and Tapio, 2009) and risk assessment, management and communication (Assmuth and Hildén, 2008, Assmuth et al., 2009, Lyytimäki et al., 2011, Lyytimäki et al., in press). All these frameworks and discussions have centered on the actual impacts or potential risks of new scientific knowledge.

Case: light pollution from road traffic in Finland

Finland is a Northern European, sparsely populated industrialized country characterized by long distances and thus the need for relatively extensive traffic and transportation (Jalasto et al., 2007; Fig. 1). Efficient logistic systems and good infrastructure are a prerequisite for economic prosperity and well-being in Finland. Roads are a vital part of the community structure, and traffic influences human actions, consumption patterns and patterns of utilizing, experiencing and coping with the environment. In addition to state roads, streets and private roads, the extensive forest truck road network in Finland makes it possible to travel to almost all areas by car (FFRI, 2010).

Fig. 1. Europe by night. Traffic and transport infrastructure are key sources of light pollution in industrialized countries with relatively low population density, such as Finland (upper right corner). In addition, urban and some industrial areas are visible. The Nighttime Lights of the World data set is compiled from October 1994 to March 1995 DMSP (Defense Meteorological Satellite Program) nighttime data of the NASA collected when moonlight was low. Areas containing clouds were removed and the remaining area used in the time series. The image is a composite of hundreds of pictures acquired by DMSP satellites which operate in low-altitude polar orbits and have the unique capability to detect low levels of visible-near infrared radiance at night. Source: http://visibleearth.nasa.gov/view_detail.php?id=1438, ©NASA Goddard Space Flight Center 2001.

However, it is also widely acknowledged that traffic causes environmental, health and social problems. This applies to all forms of traffic, including rail, water and air, but most importantly to road traffic (Jalasto et al., 2007, EEA, 2010). The intensity of traffic per capita or per Gross Domestic Product has been rather high but decreasing in Finland, unlike the average for the EU-15 countries and especially for the Mediterranean member states (Tapio et al., 2007). The environmental impacts depend, besides on the traffic volume, the size of the economy, available space, modal split, technology, and the characteristics of the impacted natural and human systems. Traffic per unit area has been relatively low in Finland. Consequently, problems such as traffic jams are not as severe as in more densely populated countries (EEA, 2010).

The effects of constructing and maintaining road infrastructure are rather well known and addressed in environmental impact assessments (Spellerberg, 1998, Jonsson and Johansson, 2006). The gaseous emissions and their impacts have gained much attention (Lyytimäki and Tapio, 2009). As for energy, the main concern seems to have been in the use of energy, that is, energy intakes to human action. Less attention has been paid to actual energy emissions, that is, energy outputs from human action (see Willamo, 2005, Tapio and Willamo, 2008).

The illumination of roads and streets together with vehicle lights constitute one of the most important sources of light energy emitted to the environment in Finland. Even though quantitative data are missing, it is clear that the growth of light energy emissions has been fast after the 1950s (Lyytimäki, 2006). The illuminated road network has been extended, nighttime traffic volumes have grown and vehicles and roads have been equipped with more powerful lights, even though lighting has become better focused. Currently 16% (12,400 km) of the state-owned roads in Finland are artificially illuminated (excluding 1100 km of ramps that are also often illuminated) (FTA, 2010). The length of illuminated state-owned roads has doubled since 1980. In addition, most municipality-owned streets are illuminated, although no statistics of their share are available. This figure is probably of the same magnitude as that for state-owned roads, since there are about 27,800 km of streets in Finland. Traffic also has indirect impacts on light pollution, because small particles caused by traffic influence light scattering.

Assuming the relatively brightly illuminated area to be on the average 20 m wide (twice the width of roads), the road traffic area flooded by light would be around 500 km2. Crossings, parking lots and other traffic areas may easily increase this to 650 km2, i.e. 0.2% of the total Finnish land area. This is one tenth of the ca. 6500 km2 of urban areas, which are impacted by street lighting. Less intensive light pollution from large cities can influence areas hundreds of kilometers outside city limits (Mizon, 2002). The light emissions from road lamps cause long strings or corridors that are permanently illuminated. The vehicles moving in non illuminated roads increase the total light emissions from traffic and the area impacted, even if less constantly. Also this light disperses over great distances and to larger areas beyond the immediate area of strong lighting needed for traffic safety. In addition, warning lights in high constructions and lighting towers built in part to protect traffic are visible over distances kilometers, although do not much increase the lighting levels on the ground.

Because of traffic lighting and other illumination, it is now almost impossible to find a place completely without artificial light in southern Finland, a situation that is typical for most of the industrial regions in the world (Cinzano et al., 2001; Fig. 1). This has not been recognized as a key environmental problem (Suhonen, 1994). The impact of light pollution on human well-being, for instance, through impaired sleep, has raised only occasional concern (Lyytimäki, 2006). In contrast, the assumed beneficial effects for safety, both in traffic and elsewhere, for human health (light therapy), for enterprises and even for recreation from increased lighting have been given much attention in research and beyond, especially in connection with the dark seasons (Willis et al., 2005, Leppämäki, 2006). The Finnish Road Administration has published traffic lighting guidelines (FinnRA, 2006) and the document does include the sub-title of disturbing light, but, in a telling fashion, the section includes only one sentence declaring that the FinnRA will try to reduce the amount of disturbing light coming from properties beside roads to the road.

Knowledge of light pollution as an environmental problem

Light pollution has been noted early on in connection with gas and oil field fires (Duru, 1981) and especially in astronomy (e.g. Riegel, 1973, Walker, 1973). Some researchers have already pointed out potential harmful ecological, health, economic and astronomical impacts of excessive use of light (Mizon, 2002, Narisada and Schreuder, 2004, Rich and Longcore, 2006, Navara and Nelson, 2007). However, despite – or perhaps because of – the ubiquitousness of artificial lighting and its fundamental importance for most species and societies, and the ease of observing it, relatively little research has been made in its problematic environmental and other effects, and few assessments have addressed it in a multi-dimensional manner (Hölker et al., 2010a). Only recently has the first global atlas of light pollution been produced (Cinzano et al., 2001) and the first assessment of the economics of light pollution been published, pointing to considerable impacts (Gallaway et al., 2010). Astronomers both in Finland (The Finnish Astronomical Association; www.ursa.fi) and globally (the International Dark-Sky Association; www.darksky.org), have tried to draw attention to the issue in order to reduce light pollution, but with limited success so far. However, this can be considered a weak signal of an increasing emphasis on light pollution in the future environmental policy.

Regarding the biological effects, extremely low amounts of light can disturb animals that are evolved and adapted to orient, feed, prey, reproduce or carry out other vital functions in the dark (Longcore and Rich, 2004). Light influences both behavior and physiology. Especially the production of the hormone melatonin which is crucially linked with diurnal (circadian) and other biological rhythms is easily disturbed in mammals, including humans (Gooley et al., 2011, Reiter et al., 2006, Stevens et al., 2007, Shuboni and Yan, 2010), as well as in birds (El Halawani et al., 2009, Kempenaers et al., 2010). These effects have been partly downplayed because the crucial influence of the spectral composition of light has been ignored (Falchi et al., 2011, van Langevelde et al., 2011). The biological basis of effects is also poorly understood, as shown by the discovery of new photoreceptors (Thapan et al., 2001). The ecological impacts are complex because they combine various direct and indirect positive and negative effects, depending on the time frame, environmental setting, interaction of species, and the target organisms (Santos et al., 2010).

Plants require light for their growth and survival, thus producing the biochemical energy for the ecosystems. It is therefore not surprising that generally plants do not react as strongly to light pollution as many animals do. However, strong light pollution (e.g. from street lights) during the night may disturb the growth, development, flowering and wintering patterns of sensitive plants (Briggs, 2006). The photoperiodic processes in plants, their specific types and degrees of light sensitivity and their impacts on natural communities and ecosystems are not well understood despite long-time agricultural and horticultural research geared to increasing immediate plant yield. It is usually assumed that field plants depend on natural light which cannot be much modified and that on the other hand they cannot get too much light. Indeed, artificial lighting is increasingly used in greenhouse spaces to boost plant production, resulting in light pollution that can be perceived as highly disturbing (Rogge et al., 2011).

As for human health, the possible impacts of light pollution through disruption of biological rhythms especially on melatonin production and associated cancers have been investigated (Pauley, 2004, Anisimov, 2006, Reiter et al., 2006, Kloog et al., 2009). Some work has also been done on the relationships of light and its periodicity with other disorders such as asthma (Lin et al., 2001) and the overall quality of sleep (Shea, 2003, Bephage, 2005). However, most of the medical research on light has focused on its benefits especially during the dark season for the prevention and treatment of depression, specifically the Seasonal Affective Disorder (Simonsen et al., 2011).

The detrimental effects of light pollution on biodiversity and ecosystem services have been recognized and further research has been called for (Rich and Longcore, 2006, Hölker et al., 2010b). However, few studies and assessments focusing on the ecological impacts of traffic lighting have yet been published (Hay and Kitcher, 2004; cf. Gallaway et al., 2010). Generally, searches with the keywords “traffic”, “lighting”, “environmental”, “ecological” and “impact” from scientific databases (SCIRUS and Thomson Reuters Web of Knowledge) produce journal articles that deal with topics other than light pollution (e.g. De Coensel et al., 2005). In almost all of these studies, traffic lighting is not considered a problem, and in most of the few studies examining such effects the focus is on human disturbance (e.g. Robin et al., 2007), not on ecological effects, except for studies of light disturbance mainly on birds.

Among studies that have recognized light pollution as a risk factor, Fuller et al. (2007) analyzed the effects of light pollution, along with noise, on the singing of robins (Erithacus rubecula) in an urban environment. van Bohemen (2002) dealt with effects of traffic lighting on birds, among noise and other impacts, while focusing on the aesthetic qualities of urban environments. Impacts of artificial light on birds demonstrate that it is not only the amount of light that matter but also its periodicity. Of other groups of animals, moths are among those most often studied. Johnsen et al. (2006) established the effects of nocturnal lighting on color perception of a hawkmoth species. Swaisgood (2007) investigated the effects of lighting on the behavior of zoo animals. Also Raimbault and Dubois (2005) addressed some ecological effects of lighting in connection with their study of urban soundscapes.

Measures reducing light pollution

Attention to contemporary environmental problems is cast largely through their mitigation measures (Lyytimäki and Tapio, 2009). Measures can be taken various stages in the process of generation of environmental problems (Tapio and Willamo, 2008) in order to solve light pollution problems. Problems may relate to physical phenomena or perceptions or both, and measures may be focused accordingly. The measures can be further divided in operative and more general strategic interventions, and in direct and indirect measures. On the level of root causes, human needs and actions causing unwanted impacts from traffic can for instance be minimized by reducing nighttime transport. Especially freight can also be partly moved from road to rail or maritime transport.

Subsequent to influencing root causes, emissions can be reduced and altered. As discussed by Falchi et al. (2011), the configuration, direction, shielding, filtering, location and timing of illumination sources affect light pollution levels. Light emissions can be reduced simply by turning unnecessary lamps off and directing the light carefully. These kinds of measures often require changes in the ways of thinking and behavior rather than technical changes.

Developing new technology is an often proposed solution to reduce harmful intakes or outputs (Tapio and Willamo, 2008). Reduction of excessive lighting has mainly been prompted by energy saving (Lyytimäki, 2006). For example, energy-efficient lighting sources such as light-emitting diodes have been developed. Car lamps are being developed so that the illuminated area is automatically adjusted to the shapes and curves of the road. Infrared detectors within vehicles reduce the need of street lighting. Street lighting can be adjusted to the traffic volume and to weather conditions through light sensors, instead of keeping streets constantly illuminated or adjusting lighting only to the average length of day. The spectral composition of light sources is also an important consideration for light pollution, for instance by favoring sodium lamps producing less disturbing short-wavelength (blue) light (Falchi et al., 2011).

Measures aimed to solve one problem may cause other problems elsewhere. Reducing night time deliveries can increase traffic jams in the daytime. Improved road lighting typically reduces the risks of serious accidents but it may increase the driving speeds and, therefore, carbon dioxide emissions (Mäkelä and Kärki, 2004). Installation of new white Light Emitting Diodes can increase energy efficiency but pollute the blue part of the light spectrum (Falchi et al., 2011). On the other hand, measures can be also devised to solve several problems, or they can solve other problems unintentionally. For example, noise barriers prevent light from trespassing. Trees and bushes planted because of aesthetic reasons can reduce light, noise and particle exposure and counterbalance the urban heat island effect (Bolund and Hunhammar, 1999). The relationships, dependencies and trade-offs between measures, accounting also for their preconditions and consequences, thus constitute key areas of assessment (Lyytimäki et al., in press).

Legislation and guidance related to lighting concentrates on security and aesthetic issues both in Finland and in other countries (Narisada and Schreuder, 2004). The Finnish Land Use and Building Act (1999) states that light commercials require a permit from the municipality. The Finnish Environmental Protection Act (2000) mention light as one form of environmental pollution, but does not contain any specific guidance for reducing light pollution. Generally, standards, guidelines and recommendations on street lighting concentrate on assuring that enough light is provided for different purposes and pay only limited attention to reducing light pollution (Narisada and Schreuder, 2004). It is often assumed that lighting improves security (Farrington and Welsh, 2002, Marchant, 2004;Willis et al., 2005). The perceived need for strong road illumination has increased because of high driving speeds, the growth of nighttime traffic, and demands for better safety. However, badly designed street lighting can cause glare and disturb car drivers, create dark areas between illuminated areas, and make it difficult to notice reflectors (Lyytimäki, 2006).

Forms of unawareness about light pollution

To discuss possible explanations for why light pollution from the traffic sector has not emerged as a seriously taken environmental problem, we build on an earlier typology of different forms of non-recognition (Lyytimäki et al., 2011). Light pollution can be considered as an emerging environmental problem that has not yet gained much interest but has the potential to be a serious problem in future (Munn et al., 1999). We distinguish four different but partially overlapping forms of non-recognition and unawareness that can explain the lack of recognition of light pollution. These forms of unawareness are dynamic and constantly evolving because of changes in human knowledge, attitudes and values, as well as changes in the state of the environment and society.

Recognized unawareness

By recognized unawareness we mean a situation where an actor (individual or institution) knows or suspects that knowledge about some issue is imperfect (Kerwin, 1993, Lyytimäki et al., 2011). The issue may be once learned but 'forgotten' afterwards. Often this kind of missing information can be restored simply by trying to remember it, by asking advice from others, by seeking information from relevant archives, or by practical experiments or theoretical reasoning to reproduce the information. Only in few cases the information is completely and irrecoverably missed. In some cases the information can be accidentally restored even when it is not actively sought.

The information recognized as missing may not have been possessed by the actor in the first place. For example, a land use planner or a citizen can suspect that the illumination of streets may have detrimental effects, but reasons that there is not enough information to assess their importance. Information may be non-existing or inaccessible. The actor can also lack resources (time, money, technical literacy, etc.) needed to use information that is potentially available.

False awareness

False awareness refers to a situation where an actor believes that all relevant information is possessed, even though in reality the information is insufficient, inaccurate, outdated, misunderstood or erroneous. False awareness or over-confidence is a common phenomenon in all human activities, including research. Some researchers maintain that, because of the rapid growth of scientific literature and too little resources put into data mining, evaluation and utilization, results especially from interdisciplinary research easily repeat results already produced elsewhere (Daughton, 2001).

False awareness can be maintained for a long time, especially if the issue is considered unimportant. Nighttime lighting disturbing the quality of sleep may be such an issue. Also, researchers may have difficulty to suspect, identify and prove the effects and relate them to causes, due in part to confounding factors, but also due to an innate inability to question phenomena that are very common and commonly accepted. People surrounded by constant artificial nighttime lighting may not have personally experienced natural darkness. In this case, lighting is experienced as natural, and darkness as unnatural and unpleasant, even dangerous. Roads, streets, parking lots, parks, squares and other areas without bright lighting are therefore often felt unsafe (Koskela and Pain, 2000). This easily increases demands for stronger illumination.

At least some predispositions or presuppositions must be disproved in order to correct false awareness. The presupposition of non-existing effects or risks of excessive illumination may be proven wrong based on concrete facts presented by institutions considered trustworthy and unbiased. For example, the International Energy Agency (IEA, 2006) has estimated that worldwide carbon dioxide emissions caused by all illumination are about two thirds of the emissions of private cars, and that illumination would use 80% more energy in 2030, if current trends continue. These kinds of concrete estimations with numerical values can be easily used in social debates related to light pollution.

Deliberate unawareness

Perhaps the most obvious reason for an environmental issue to gain only limited attention is that the issue is not considered to be important and therefore additional information is not sought for. There may be no current perceived need for the information, especially when an issue has not even entered the cognitive horizon of actors. After this happens, acquiring the information may be considered useful, but too costly or difficult compared to the gains achieved. In many cases the actor trusts that somebody else will acquire the information and act based on it. Furthermore, incorporating novel issues to the planning processes may be difficult if an authority or land use planner is obliged to focus on information related only to narrowly defined impacts.

Deliberate unawareness may be related to perceived imbalance between the possibilities and the requirements to act. The changes needed may be considered too radical and an actor can actively try to avoid stressful information and cognitive dissonance (Festinger and Carlsmith, 1959, Kaplan, 2000). With environmental and health risks, this is a particularly important type of non-recognition, as the emotional stress associated with such risks easily cause denial and repression, along with overreactions. For a single actor, the possibilities to influence the development of structural issues such as street lighting may seem non-existent. This may be partly because the impact of the accumulation of single decisions and actions is unnoticed. For management, it is important to seek for and be aware of the critical points at which path dependence may be influenced.

Concealed awareness

Concealed awareness means that the information is possessed by an actor who is not willing or able to pass the information to others. Three different forms of concealed awareness can be discerned. Firstly, it can be about purposeful omitting of unpleasant facts or viewpoints in order to secure the interests of the actor. The history of environmental protection is full of examples when it has been attempted to silence an issue considered as a threat (e.g. Kroll, 2001). This can be done, e.g., by downplaying the importance of the issue, misguiding the discussion off track, labeling the opponent as ridiculous or untrustworthy, or attempting to subdue the discussion. Financial motives often explain these attempts (Muggli et al., 2004). On the other hand, also the importance of issues including threats can be exaggerated, i.e. the awareness of their relative insignificance can be concealed, even out of self-interested motives.

Secondly, concealed awareness may be a benevolent attempt aimed to secure public good. For example, a land use planner may reason that discussion about the potential effects of light pollution is not needed, because it can create unnecessary fears and redirect attention and resources from more important issues. When suspicion about the potential harm of a certain issue or activity emerges, an exaggerated perception of the impacts can be induced, before science can produce information about their order of magnitude and ascertained characteristics. Different time cycles between the media and science contribute to this, because the media does not wait for scientific studies to be completed. Furthermore, science cannot guarantee absolute certainty. Media hype can create demands for quick actions to remove potential hazards, which may lead to unnecessary or even harmful actions (Mazur, 2004).

Thirdly, the actor possessing the information may want to deliver it to others, but is lacking the resources and the opportunity to do this. These resources may be financial but also other resources such as the courage to speak up about controversial issues, the expertise to use technical vocabulary, or the social and professional prestige. Perceived positive implications of lighting may alone be sufficient to inhibit people to state reservations about artificial lighting.

Potential solutions to unawareness

The technological development during the last century heightened the impression of electrical lighting as a positive thing, as highlighted, e.g. by Oliver Sacks (2001) in Uncle Tungsten. More recently, the development of information society, characterized by the increasing use of light as a method to deliver and present information, has increased positive reactions towards the use of light. Primeval stories about the evil lurking in the dark are reproduced in fiction films. Thus, a ring of silence (Noelle-Neumann, 1991) related to light pollution can make people to be content with excessive use of lighting even when there are well-justified doubts about possible drawbacks.

In order to break the ring of silence, measures encouraging and enabling critical and open-minded deliberation are needed. The information measures to combat each category of environmental unawareness are different (Table 1). Recognized unawareness and false awareness can be efficiently dealt with by measures aiming for increasing factual knowledge on light pollution. In the case of deliberate unawareness ethical reasoning or emotional advocating is may be required in order to effectively question the overconfidence on the adequacy of current knowledge. The case of concealed awareness calls for raising critical activist voices on the issue. These activists can include, e.g. non-governmental organizations or authorities demanding open discussion of the costs and benefits of potential disclosure of the information.

Table 1. The prerequisites and measures to various types of environmental unawareness.

Type of inattention	**Facts**	**Values**	**Potential information strategy**
Recognized unawareness	Not known	Pro action	Improved access to facts
False awareness	Erroneous	Variable	Mediation of facts
Deliberate unawareness	Set aside	Contra	Ethical/emotional advocating
Concealed awareness	Hidden	Contra	Critical campaign

Note: Facts refer to level of information publicly available. Values refer to perceptions and attitudes towards implementing environmental policy measures focusing on the issue.

Concluding remarks

Light pollution is an emerging issue that has to be studied with interdisciplinary approach and managed with participatory methods taking into account aspirations, values and knowledge of the people (Hölker et al., 2010a). An agenda for further research include both natural and applied natural such as engineering as well as social science perspectives. Ecological research is needed especially regarding the spectral effects that are invisible to human eyes and indirect effects on ecosystems through altered behavior of organisms and entire communities, including species interactions. Key social science issues include recognition of light pollution, specifically in policy-level traffic planning; energy policy opportunities including those in energy saving, energy source choice and energy conversion approaches.

We also need studies and experiments combining the project-level planning of traffic routes (e.g. lamp configurations, timing of lighting) with social science approaches focusing on topics such as perceived safety, aesthetic pleasure and sense of place. In an increasingly urbanizing world, there is an overall need for sustainable urban area lighting that can be achieved through balanced integration of ecological, socio-cultural, economic and technological considerations that includes both the benefits and the costs of artificial lighting.

The dominant assumption, that traffic and other ambient lighting is beneficial, stems partly from the notion that darkness presents threats and inconveniences not only to traffic but also more generally to human aspirations. This value frame should be understood as one key context element for the assessment of energy-related environmental impacts. Within such a frame it is easy to consider possible detrimental effects of light as insignificant or non-existent. Moreover, based on our model and review of the evidence, such attitudes are to a great degree not a result of conscious consideration or reflection. Instead of deliberate unawareness they often are a result of false awareness.

Lighting and illumination are culturally closely connected with the ideas of progress, modernity and development – the Enlightenment. Many cultures and religions use light as a symbol of both goodness and godliness whereas darkness is related to ugliness, chaos and evil, and it is something to be feared and eradicated (Lyytimäki, 2006, Campanella, 2007). This is also biologically explained: As a day-active species, humans are adjusted to sensing in well-lighted environment. Hence, darkness is opposed both instinctively and ideologically, and fears related to darkness can easily be over-emphasized. At the same time, the necessity of darkness and the natural periodicity in light for life goes easily unaccounted and even unimagined.

A polarization may gradually develop between a lighting-promoting approach that interprets safety from the narrow perspective of social control against 'dark forces' and a new, more ecologically oriented approach acknowledging that lighting can also be excessive and harmful. On the other hand, such polarizations may be accompanied by new balances in attitudes and approaches and new consensus views, which are, however, relative and liable to change. Decision-makers, practitioners and scholars should be aware and alert about different reasons and motivations for forgetting and non-recognition especially when different environmental impacts are compared and prioritized. Searching for win-win solutions is especially important. Developing land use strategies aiming at reducing light pollution can lead to monetary savings, energy saving and mitigation of climate change, as well as preservation of biodiversity and ecosystem services dependent on natural darkness.

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