Tackling Light Pollution for Sustainability: an Approach for the Vesancy-Versoix Bio-Corridor of Grand Genève

LUDWIG, Kerstin & Collaboration
BALSIGER, Jörg (Collab.)

Abstract
Do we still need the pristine night sky? Indeed, there is a problem. Globally, more than 80% of all people live under light polluted skies. The trend increases exponentially due to urbanization, road traffic, energy-efficient lighting technologies, municipal policies, and unawareness or rejection of the negative impacts of light pollution on all life forms and/or of possible solutions. Light pollution is unnecessary and/or excessive artificial light at night appearing as sky glow, glare, trespass or clutter. It fragments landscapes, harms human well-being and biodiversity, wastes energy and threatens food security. It also decreases our levels of empathy. From Geneva, Switzerland, one must travel more than 1,300 km to get away from it. In the cross-border setting of a Franco-Swiss biological corridor of Greater Geneva, we aim to tackle light pollution for sustainability. The analysis of two representative communes in the corridor shows high levels of light pollution (and an increasing rebound effect due to adoption of low energy-consumption lighting) as a result of inadequate socio-environmental policies. To reach the [...]
Tackling Light Pollution for Sustainability – An Approach for the Vesancy- Versoix Bio-Corridor of Grand Genève

Jury members:
Professor Dr. Jörg Balsiger, University of Geneva and Mr. Vincent Scattolin, external expert at Municipality of Divonne les Bains and Community of Communes in Pays de Gex

Geneva, 17 November 2017

Working Paper for UNIGE Open Archive, Revision dated 28 February 2018
Table of Contents

Executive Summary  iii
Introduction  9
Chapter 1 – Light Pollution and the Project  11
Chapter 2 – A Short History of Sustainable Development  15
Chapter 3 – SDGs and Light Pollution  34
Chapter 4 - Case study analysis for the Vesancy-Versoix corridor  49
Chapter 5 – DPSIR Analysis  57
Chapter 6 – Conclusions and Recommendations  64
Appendices  86
Acknowledgements  109
Bibliographical references  110

List of Tables

Table 1: Impact of light pollution on selected SDG targets, and impact of selected SDG targets on light pollution
Table 2: Reasons for the H/M/L impact ratings applied to light pollution in relation to the selected SDG targets
Table 3: Cross-impacts of light pollution and 13 selected SDG targets
Table 4: Prioritization of SDG targets relating to light pollution
Table 5: Data on the two communes
Table 6: Colour levels used in the New World Atlas maps and zoom in on study perimeter
Table 7: Prioritised actions to reduce light pollution, grouped by SDG targets

List of Figures

Figure 1: Simplified system and its dynamics
Figure 2: Tensions of sustainability in the search for equilibrium
Figure 3: Planetary boundaries
Figure 4: Risk of level of extinction (in %) of 10,350 animal, plant and mushroom species studied under the Red List
Figure 5: (a) At night in Switzerland, (b) Light pollution in Europe, and (c) Forecast light pollution in Europe if transitioned to 4000 k CCT LED technology with the photopic flux of currently installed lamps
Figure 6: Strong sustainability
Figure 7: Vesancy-Versoix corridor
Figure 8: The new world atlas of artificial sky brightness - Grand Genève
Figure 9: Four ANPCEN labels
Executive Summary

Background

Since the introduction of electric lighting, humanity has been ever more rapidly transforming our planet’s night environment, altering the natural cycle of day and night that has guided evolution since the beginning of life. This process has quickened significantly over recent decades due to urban growth and increased wealth. The introduction of new low-energy, low-cost lighting technology in recent years has resulted in a rebound effect, causing lighting at night to accelerate even further. According to a 2016 study in Science Advances, about 83% of the world’s population and more than 99% of the U.S. and European populations already live under skies that are “light-polluted”. In France, artificial light at night increased by 94% since 1990. In Switzerland, light emissions into the night sky more than doubled between 1994 and 2012.

This report considers light pollution as the excessive and unnecessary presence of artificial light at night that affects the night environment. The extent of light pollution varies depending on the light’s intensity and duration, the distances that it covers and its impacts. Light pollution results, for instance, in the sky glow that can be seen hovering over cities over long distances. It can also locally cause a blinding glare, which is disturbing and even dangerous. Clustering of lights is another manifestation of light pollution, as is the trespassing light that enters homes and other private spaces from without.

Light pollution is now known to have substantial effects on all living beings. It impacts upon human health, affecting circadian rhythms, sleep patterns and hormonal balances that can lead to serious physical and mental illness. By restricting the view of the night sky, it additionally affects human emotional states, spiritual richness, culture and science (e.g. astronomy). There is strong evidence to suggest, furthermore, that excessive light at night may diminish – rather than increase, as is commonly believed – people’s safety and security.

Very importantly, light pollution also has a dramatic impact on ecosystems, affecting feeding patterns and growth, migration, rest, reproduction and the resilience of animals, plants and other life forms, including micro-organisms. Loss of biological diversity is considered the most serious environmental problem facing our planet today. Out of the nine so-called “Planetary Boundaries” defined by Steffen et al. (2015), it is one of four areas (the others being biogeochemical flows – notably of nitrogen and phosphorus, land use change and climate change) where humanity has already exceeded the safe boundary and entered a danger zone. Globally, the rate of extinction per million species per year is 100 times greater than is specified in the boundary. Both France and Switzerland are facing substantial losses of biodiversity. Public perceptions, however, are far from this reality: over 70% of Swiss surveyed in 2016 believed, for instance, that the state of biodiversity in the country is “very good” or “fairly good”, despite evidence to the contrary. Nevertheless, the Swiss see conserving biodiversity as an essential “duty to future generations”, as a “connection” to nature and its “beauty”, and as a “moral obligation”. This shows that there can be a very large gap between the actual and the perceived state of a country’s biodiversity, and between peoples’ intentions and their actions. Besides the ethical considerations, given the interconnections and dynamics of living systems, humans depend on nature. Destroying nature means cutting humans off from the resources necessary for our survival.
Tackling Light Pollution for Sustainability – An Approach for the Vesancy-Versoix Corridor

Unnecessary or excessive artificial light at night also of course results in a waste of energy and of money, contributing substantially to greenhouse gas (GHG) emissions and to poor use of resources.

The above begins to illustrate the consequences of light pollution on what today we call “sustainable development”. Over the course of history, certain cultures have realised the obligation to protect and use the land and its resources in such a way that it will continue to serve their peoples into the future. In the face of the increasing dangers being faced by our planet, the international community has been discussing this matter from a global perspective since the early 1970s. In 1987, the Brundtland Report of the United Nations World Commission on Environment and Development formally defined sustainable development as “... development that meets the needs of the present without compromising the ability of future generations to meet their own needs...”. It thus must aim to achieve not only intragenerational but also intergenerational justice.

Nevertheless, there continue to be differing views on how to approach sustainability, i.e. how to balance tensions and reach an equilibrium within the so-called “sustainability triangle” encompassing economic development, improvement of social conditions and the protection of nature. The so-called “weak” sustainability approach considers “natural capital” (i.e. nature as a resource) to be substitutable with social and economic capital. It aims to enhance economic efficiency and minimise the use of resources while improving human wellbeing. It places no limits on the use of natural capital, however, as long as the total end value for humans is increased. Thus, it does not recognise the Planetary Boundaries per se. Under weak sustainability, light pollution is an issue to be tackled inasmuch as it diminishes human wellbeing – either directly or by harming plants and animals that are beneficial to humans (ecosystem services).

The “strong” approach to sustainable development, on the other hand, seeks to build significantly upon the Brundtland Report definition. It advocates that economic development is subordinate to the social dimension, and that both must comply with the obligation to protect the planet’s environment and natural ecosystems. This protection is seen as an ethical imperative, rather than merely a utilitarian good. Under this approach, humans would have the obligation to reduce to the absolute minimum any light pollution that harms the resilience of natural systems in and of themselves, whether they are directly beneficial to us or not.

In 2015, the international community made an unprecedented decision to embark on “transforming our world” with Agenda 2030 involving 17 Sustainable Development Goals (SDGs) and 169 associated targets. While none of these specifically refers to the issue of light pollution, many of these targets will both affect and be affected by levels of light pollution. This report outlines the specific links between light pollution and selected SDG targets, as outlined in the methodology below.

In short, light pollution has systemic causes and consequences that affect all three dimensions of sustainable development, involving feedback loops in all directions. Dealing with light pollution is thus not only critical: it requires a systemic, transdisciplinary approach to ensure coherence in policy decisions and implementation measures. However, light pollution has only relatively recently been identified as a serious problem by scientists and relevant authorities (note that it is not even mentioned in the SDGs), and it is little known or appreciated by the general population. In fact, in many cases there is strong opposition to turning back the “light tide”, for psychological, cultural, socio-economic and political reasons.
Tackling Light Pollution for Sustainability – An Approach for the Vesancy-Versoix Corridor

Thus, building awareness of the problem (through, e.g., transformative literacy) and developing a consensus towards finding the best solutions locally and globally are a high priority. Fortunately, in many cases the solution can be as simple as turning off a light switch. Technology can help, but to be effective it must remain subordinate to changes in attitudes, economic incentives, institutional arrangements and public policies. As demonstrated in a small but growing number of locations worldwide, the outcome can be the creation of fully dark or light-free zones (e.g. in natural areas), deep night light shutoffs, dimming, shielding and better downward focusing of lights, and lighting governed by movement sensors and others.

The question is: will humanity respond to this challenge with a paradigm shift?

The purpose of this project

The purpose of this academic research project has been to: (1) assess the levels of light pollution in the Vesancy-Versoix biological corridor, one of the cross-border biological corridors in the Franco-Swiss agglomeration of the “Grand Genève” region; (2) identify general attitudes towards this issue amongst the local inhabitants; and (3) suggest measures appropriate to the region and its populations aimed at reducing light pollution over the medium-to-long term within the context of efforts to promote sustainable development – in particular to halt and reverse biodiversity loss as well as to enhance human health and well-being.

Approach and methodology

The project approach involved: (1) carrying out a review of the relevant scientific literature; (2) an assessment of the levels of light pollution in the corridor area as detected through satellite data derived from the 2016 published article in ScienceAdvances by Falchi, F. et al.’s *The New World Atlas of Artificial Night Sky Brightness*; (3) carrying out selected informal interviews with local authorities and with “people in the street”; and (4) collecting relevant data relating to two sample communes in the corridor – Divonne les Bains in France and Mies in Switzerland – including data available from municipal authorities, other regional and national administrations, and from non-governmental organizations. These two communities were selected because they reflect the diverse though similar historical, geopolitical, demographic and environmental aspects of the corridor as a whole, specifically: (a) encompassing urban, suburban, agricultural and natural environments and habitat types (biomes); (b) having resident populations – often short-term – that depend typically on daily commutes to Geneva or Lausanne for employment; (c) not having, as yet, adopted specific measures on sustainability nor to reduce light pollution; (d) experiencing substantial changes in land use and habitat fragmentation due to construction. Divonne les Bains was also considered an interesting location due to its high reliance on health-based tourism and wealthy secondary homes.

Adopting a systemic approach has helped to (a) identify the *drivers* and *pressures* that have led to the current *state of light pollution* in the corridor, (b) to make broad assumptions about its *impacts* based on global experience, and (c) to suggest appropriate *responses* for dealing with this problem.

Although – as noted above – light pollution is not directly mentioned in the SDGs, the examination of cross-impacts between light pollution and 13 selected SDG targets was made possible thanks to the identification of the Weitz, N. *et al.* study in 2017 analysing the cross-impacts for systemic and contextual priority setting amongst a group of 34 SDG targets relevant to Sweden. Given the many
similarities in development levels, culture and geography between Sweden and the Greater Geneva area – and despite the obvious differences – this study was felt to be a good starting point for gauging the system dynamics and links between light pollution and sustainable development. In terms of their cross-impacts with light pollution, this allowed prioritising the above mentioned 13 selected SDG target areas in the following order: biodiversity (15.5), transport (11.2), effective institutions (16.6), food production / agriculture (2.4), technical / vocational training and education (4.4), infrastructure / clean technology (9.4), affordable housing (11.1), energy efficiency (7.3), waste (12.5), water-related ecosystems (6.6), non-communicable diseases (3.4), forests (15.2), and renewable energy (7.2). This analytical framework supports decision-making in prioritizing for policy action relating to tackling light pollution based on the potential impacts of these actions on sustainable development.

Results and findings

Following, are the main findings of the project:

1. Satellite and visual observations show that there is a high degree of light pollution / artificial light at night in the region, as represented by the two sample communities of Divonne les Bains and Mies. The satellite data specify a level of pollution affecting the populations at these two locations that ranges from (a) the inability to view the Milky Way, up to (b) cone receptor stimulation in the eye. As cone receptors are normally meant to be used only during the day, this means that true night conditions are non-existent as people must live (without using their natural rod receptor-based night view) under an artificial twilight.

2. Attitudes of the local population towards light pollution and biodiversity – as identified through informal interviews – ranged from (a) a complete lack of awareness and/or denial through to (b) a mixed understanding of the issues. Many in the latter group nevertheless expressed a desire and eagerness to reduce light pollution in the region. Some were conflicted with concerns of security, while being unaware of possible measures to combine both goals.

3. The main drivers causing increased light pollution include: (a) socio-economic and demographic factors, including continued increases in population, urbanization, commercial activity and road traffic, and the fragmentation of landscapes; (b) psycho-cultural factors relating to the learned fear of darkness (for example through fairy tales, biblical symbolism of light and darkness, etc.), the need for security, and the concept of light being equated with “progress”; (c) changing light technologies, particularly the widespread availability of recent (white-blue spectrum) light-emitting diodes (LEDs); and (d) municipal policies and private / public sector investments promoting LEDs as a means to reduce energy costs while increasing illumination. In fact, global and local data appears to confirm the rebound effect in action, whereby more and brighter environmentally unfriendly white-blue light LEDs are being installed due to their reduced energy consumption and cost. Another immediate consequence of these changes is the increase of (non-recycled) waste from old lighting systems being replaced.

4. Limited measures have been undertaken over the last years by some cantonal and municipal authorities in both France and Switzerland to reduce light pollution, e.g. through dimming, complete deep-night shut-off, and installing movement detectors. But by far most communes in the region seem to remain either unaware of light pollution or have been unable or not yet willing to act upon this issue. In fact, some of the existing laws and regulations in France and the non-binding
Federal recommendations in Switzerland concerning light pollution are only being partly followed with limited enforcement (for example, shutting off all shop lights in France after 01h00 at time of research). Awareness campaigns are being carried out by environmental organisations and official bodies. Even so, the response is lacking: the regional conference on light pollution held in Geneva in March of last year was attended by only half as many elected officials as were expected.

5. There is no specific data available yet for the region (or for any other parts of the world, as far as the author is aware) allowing to correlate light pollution with specific physical and mental health impacts across the population. Nevertheless, given the evidence provided by recent scientific research to this effect, it may be assumed with a reasonable degree of confidence that these impacts are widespread, significant, and that they influence both the wellbeing of the population and their economic productivity (e.g. due to stress, fatigue, lost work time, and influencing the next generation in their lifestyles).

6. Regarding the impacts on biodiversity, both France and Switzerland have documented a substantial decrease in biodiversity (extinction of species), witnessed also by the region’s residents. However, the precise numbers of species that are extinct or facing extinction at the local level, the extent of these declines and their related causes (including the impacts of light pollution) are not yet fully known, and much research in this regard still needs to be carried out. The main reasons for local loss of biodiversity would appear to be related to the increase of population, urbanization and associated road traffic (all of which are associated with light pollution), along with agricultural practices resulting in a reduction and fragmentation of natural landscapes and an increase in chemical pollutants. Assuming that the Vesancy- Versoix corridor profile is broadly similar to the overall profile for Switzerland (since this is a biome of temperate broadleaf and mixed forests), one can estimate that the Biodiversity Damage Potential for the corridor is 0,39. To reach the Aichi targets by the year 2020 under the Convention of Biodiversity, this would have to be reduced by 0,16, i.e. by almost 60%. Reducing light pollution can be one of the means to achieving this.

7. There is limited offer within the public educational and cultural environment in the region about the problem of light pollution and its impacts, and about possible solutions.

Conclusions and recommendations

Light pollution is a key issue for the Vesancy-Versoix corridor and for the Grand Genève region. The main source of light pollution is public lighting, but others are road traffic, homes, illuminated buildings and trees, commercial centres, luminous advertisements, sport and parking areas. Light pollution has significant impacts on humans and on nature, even though these impacts are difficult to measure, requiring a long-term vision as well as concrete, short-term actions that can be linked to specific SDGs and targets.

Recommendations need to specify what type of lighting is appropriate, when it is appropriate and where it is appropriate. To be as sustainable as possible, the type of lighting needs to be no brighter than needed (i.e. as dim as possible at any point in time) and of a colour in the spectrum that does the least damage to living beings, usually in the yellow range. When it is appropriate means that sustainable lighting also must be time-based, i.e. turned on only when required for a specific purpose and otherwise turned off. Finally, where it is appropriate means that it should be directed specifically at those locations where it is required (e.g. shielded lights on roads), and not allowed anywhere else outside of those.
locations. This also means that no light should exist unless it is performing a clearly specified function that justifies illumination. If alternative means exist to perform a given function (e.g. an anti-theft alarm system), they should generally be preferred.

An effective strategy is required to overcoming the barriers to achieving the vision and the specific goals and targets.

**Vision for 2030**

The main elements of this vision are as follows:

1) Establishment of an association (or agency) of communes of the Grand Geneva area with dedicated transdisciplinary working groups on sustainable lighting, including relevant public and private sectors, non-governmental organizations and citizens concerned with the economic, social and environmental dimension of sustainability. This association / agency would aim to (a) develop an understanding of systems thinking, the impacts of light pollution on sustainability, planetary boundaries, and ethical considerations; (b) share experiences and provide mutual support; (c) develop awareness campaigns; (d) advise on policies and regulations; (e) act to resolve challenges related to light pollution in the region; and (f) discuss long-term strategy for citizen participation on lighting management.

2) Widespread adoption in the region of measures to combat public and private light pollution, including: (a) harmonized regulations; (b) replacing all sources of light pollution that are “worst offenders”; (c) ensuring all new investments in lighting focus on reducing light pollution; (d) including light pollution reduction mechanisms / specifications in construction permits; (e) creating a collaborative funding mechanism to promote light pollution-free systems; (f) ensuring no light source reaches natural areas; and (g) light reduction mechanisms implemented in the region’s communes such as dimming, shielding, late night shut-off, movement and user-activated lighting systems, and off-the-grid solar powered lighting systems.

3) Adopting security and safety measures that avoid reliance on continuous full-strength lighting, e.g.: (a) self-defence courses, particularly for women; (b) fostering civil courage and altruism; (c) neighbourhood watch initiatives; (d) movement-activated lighting systems; (e) mobile device-based danger alert; and (f) rapid (e.g. drone-based) response systems.

4) Increasing population awareness and promoting lifestyle changes to foster “strong” sustainability, e.g. through: (a) cultural activities (e.g. museum exhibitions, storytelling, art, music and theatre); (b) organising / promoting night walks and other “light-less” night activities; (c) promoting natural, unfragmented habitat where possible, including private properties, to foster biological diversity; and (d) encouraging collaborative community-based approaches and actions aimed at changing people’s attitudes and values, and working to overcome legal, economic, financial and technological barriers. This should aim to reduce light pollution not only in public spaces but also in private homes.

**Concrete actions**

The report also outlines a series of concrete actions that can be taken in the short term to tackle light pollution while moving towards the above vision, specifically relating to the 13 SDG targets referred to
above in the methodology, thus cementing the link between tackling light pollution and sustainable development.

**Barriers to change**

The greatest challenge to achieving this vision and attaining the goals is changing peoples’ attitudes and values regarding light pollution. Barriers include lack of interest and concern, feelings of impotence to tackle the problem, absence of any past experience reference points (e.g. concerning the beauty of the night sky and nature) to appreciate the need for change, enjoyment of strong lights regardless of their consequences, and feelings of insecurity and the belief that strong and continued lighting is the best way to deter crime and avoid accidents.

Other barriers include legal systems and fiscal / financial incentives that are not yet fully aligned with light pollution reduction strategies, although these are progressively improving. More and more institutions are taking up the cause of combatting light pollution, particularly environmental protection organisations, but many communal authorities (where decisions are taken) and lighting companies are still lagging. Limited availability or funding and competing priorities, absence of information for life-cycle analyses and valuation of ecosystem services, and the lower cost of the more light-polluting technological options are also constraints to change. Technological barriers additionally include uncertainties regarding the different light spectra impacts on different species, as well as continuing technological developments and costs.

**Strategy**

The key strategy elements aimed at overcoming these barriers to achieving the vision and goals include:

1) Adoption of indicators to measure progress on reducing light pollution and promoting biodiversity. These indicators – and relevant data collection – are essential to knowing whether efforts to achieve the above goals are moving in the right direction, and how rapidly.

2) Developing a communications strategy based on targeted information, promoting empathy, encouragement of systems thinking, intrinsic and extrinsic motivation, building citizen participation and collaboration, and encouraging behavioural change.

3) Identifying and nurturing change leaders and building cross-functional “diversity” teams to bring in a wide array of knowledge and experience, for which strongly fostering citizen participation is essential.
Tackling Light Pollution for Sustainability – An Approach for the Vesancy-Versoix Corridor

Introduction

For many centuries we humans navigated the seas with help from the stars, and the stars drove us to create magnificent œuvres d’art. But, today, do we still need the pristine night sky?

Our lives today in many parts of the world are lives of rapid change, digital transformations, globalization, and of having to confront more and more natural and man-made disasters. We face uncertainty and huge threats to humanity due to continuous declines in biological diversity and in food security, overpopulation, and changes in our land-use systems and in our climate, amongst others. The complexity of the interactions and the dynamics of systems in this global picture is hard for us to grasp. We still carry out analyses and make decisions using linear thinking silos, and our attempts to correct problems often have unintended consequences, creating new problems for which we seek yet more solutions. Short-term solutions tend to focus on technology and on economic growth, rather than on institutional and social transformation. We can master the technologies. That is relatively simple. But our modern societies have not yet mastered what many ancient peoples were able to master: how to live sustainably, and how to live in harmony with nature. Artificial light at night is an example of a technology solution that began as a useful tool for development but has turned out to become now a threat to human health, to biological diversity, to food production, and to the altruism needed for our societies to function humanely. Where artificial light at night is not necessary, or when it comes in excess, or when it causes harm, then indeed: we are facing light pollution. The sky glow of our cities invades our vertical and horizontal surroundings for dozens if not hundreds of kilometres; glaring light can create road hazards and facilitate crime; trespassing light entering homes and other private spaces from without can harm our sleeping patterns; and light clutter beguiles discomfort. All of these forms of light pollution build barriers for fauna, flora and humans and so, as we observe, we find we need to adapt our behavioural responses accordingly.

Due to the complexity of our environmental and social challenges, we need to bring together science, society and systems from various disciplines in a collaborative manner to find more comprehensive solutions. By jointly defining the problem(s), the system’s dynamic interactions, and the potential risks, we co-create the capacities needed to implement sustainable policy transformations and solutions (within technological, economical, cultural and institutional dimensions, based on transformative literacy) for the long-term survival of life on Planet Earth.

The pristine night sky - at least for most parts of the “developed” world – has been lost already. But it can be regained. It is everyone’s responsibility to ensure that we deal with light pollution decisively in order to leave, once more, a beautiful heritage for future generations.

With this aim as its setting, the purpose of this paper has been to assess the nature, causes and impacts of light pollution – and its threats to sustainability on our planet – through a comprehensive review of the trans-disciplinary literature from across the globe on this topic. The paper focuses particularly on the impacts of light pollution on biological diversity, human wellbeing, urbanization and energy.

Given that understanding, promoting and achieving sustainability is our ultimate goal to be able to live successfully on this planet, this paper provides a historical overview and a definition of what sustainability is all about. It emphasizes sustainability’s three – environmental, social and economic – dimensions while explaining the tensions that arise amongst these when attempting to achieve an equilibrium and offering a troubling look into the subject of our planetary boundaries². A detailed

1 Schneidewind, U. (2013)
2 Rockström, J. et al. (2009)
analysis is carried out regarding the interactions and cross-linkages between light pollution and 13 key Targets associated with the Sustainable Development Goals (SDG). This analysis allows us to arrive at a prioritization for policy-makers and community participation in potential actions to tackle light pollution.

The paper then attempts to apply this transdisciplinary knowledge to assessing and explaining the levels of light pollution at local level within the Franco-Valdo-Genevois trans-border biological corridor\(^3\) of Vesancy-Versoix. For this purpose, due to their historical, geopolitical, demographic and environmental features, two representative case studies were chosen to elucidate and evaluate the challenges of light pollution: Divonne les Bains in the Department of Ain in France, and Mies of the Swiss Canton of Vaud. The research finds that the levels of light pollution are high at both locations, with potential impacts on loss of biological diversity, damage to human health and wellbeing, and waste of energy, which can be extrapolated from the general scientific findings. The paper finally proposes approaches to reducing light pollution in the region, within the context of a longer-term sustainability vision and of a strategy to realize this vision.

CHAPTER 1 – LIGHT POLLUTION AND THE PROJECT

What is light pollution?

This research project and paper is about reducing light pollution to protect biodiversity and to enhance people’s wellbeing in one of the eight biological corridors of the Greater Geneva area.

It considers light pollution as the excessive and unnecessary presence of artificial light at night that affects the night environment and causes harm. The extent of light pollution varies depending on the light’s intensity and duration, the distances that it covers and its impacts. Light pollution results, for instance, in the sky glow that can be seen hovering over cities over long distances, hence even affecting protected natural areas in a distance. It can also locally cause a blinding glare, which can be disturbing and even dangerous. Clustering of lights is another manifestation of light pollution, as is the trespassing light that enters homes and other private spaces from without.

Light pollution is now known to have substantial effects on all living beings. It impacts upon human health, affecting circadian rhythms, sleep patterns and hormonal balances that can lead to serious physical and mental illness. By restricting the view of the night sky, it additionally affects human emotional states, spiritual richness, culture and science (e.g. astronomy). There is strong evidence to suggest, furthermore, that excessive light at night may diminish – rather than increase, as is commonly believed – people’s safety and security.

The above definition implies that, if the light is unnecessary, it should be turned off. If it is excessive, it should be turned down, especially if it does any harm to the environment or to people. This can lead to debate on questions such as “what do we mean by unnecessary?”, “what do we mean by excessive?”, and “what do we mean by harm?”.

The answers to the first two questions are often subjective. They relate to how much light at night we may feel we need, and when and where we need it, for our own purposes, whichever these may be – for instance: to find our way around at night, for safety and security, to participate in night-time activities
Tackling Light Pollution for Sustainability – An Approach for the Vesancy-Versoix Corridor

(as an extension of the day), and even for aesthetic purposes, e.g. just to enjoy the lights, as we do with outside light decorations. Some people may feel the need for more light, and others for less.

The answers to the third question are more objective, as “harm” can be more objectively gauged. As we shall see in this paper, artificial light at night harms all kinds of fauna, flora and micro-organisms, accustomed through eons of evolution to the natural cycles of day and night for feeding, growth, reproduction, movement and rest. Artificial light at night can also harm the physical, mental, emotional and even spiritual wellbeing of humans, especially if it disturbs our vital sleep patterns and damages our eyes. It breaks our connection with nature and enjoying the beauty of the night sky. Finally, our artificial light does not come free: to produce it requires energy, and this energy must come from somewhere. If the source damages the environment in one way or another – e.g. by generating greenhouse gases that contribute to global warming – this too can be considered a harm.

By this definition, we need to find the right balance between the amount of light that we really need against the amount of light that causes harm. How this balance is settled will vary, depending on culture and history, personality and disposition, and ethical perspective – i.e., do we have the right to cause harm and even to destroy anyone or anything just for the purposes of our own convenience or benefit?

In this paper we will be considering issues of sustainable development in relation to light pollution. We will see that there are different perspectives on sustainable development – i.e., development that meets current needs while protecting the needs of today’s and future generations. These different perspectives also reflect the question of balance raised above. A so-called “weak sustainability approach” to light pollution might lean in favour of meeting human needs and wellbeing, while trying as much as possible to avoid harm to nature. A “strong sustainability approach”, on the other hand, would lean heavily in favour of avoiding the harm. In other words, it would consider light pollution to be any amount of light – whether it is needed or not – that begins to harm the capacity of nature to regenerate and sustain itself.

A description of the system and its dynamics

The detailed system encompassing light pollution and its impact on biodiversity in the Vesancy-Versoix biological corridor is described in Annex 1. The relationships and flows amongst the system’s elements and its sub-systems are outlined in this graphic. The elements money, material, energy and information are directly and indirectly included. Figure 1 represents a simplified view of the system. The symbol “+” equals “increase”, symbol “-” equals “decreases”.

The research project

The purpose of this academic research project has been to: (1) assess the levels of light

---

4 Some different perspectives on this matter are mentioned in the BBC article of Wheeler, B. (2017)
5 For some considerations on communication, ethics and environmental conservation, see Eser, U. (2016)
Tackling Light Pollution for Sustainability – An Approach for the Vesancy-Versoix Corridor

pollution in the Vesancy-Versoix biological corridor, one of the cross-border biological corridors\(^6\) in the Franco-Swiss agglomeration of the “Grand Genève” region; (2) identify general attitudes towards this issue amongst the local inhabitants; and (3) suggest measures appropriate to the region and its populations aimed at reducing light pollution over the medium-to-long term within the context of efforts to promote sustainable development – in particular to halt and reverse biodiversity loss as well as to enhance human health and wellbeing.

This paper will begin with an overview perspective on sustainable development and its links to light pollution, based on a reasonably comprehensive review of existing literature regarding the nature, causes and impacts of light pollution, and regarding also some relevant experiences to date in tackling light pollution from the technological, social-organizational, economic and cultural perspectives.

Based on this understanding, this paper will then focus on the question of light pollution in the specific context of the Vesancy-Versoix trans-border corridor and provide suggestions on how to reduce it. For this, it will take account of two case studies: one commune on the French side of the corridor, and another on the Swiss side. It will attempt to draw conclusions from these two cases regarding the extent of the problem, and the drivers and pressures that are causing it. While realising and accepting the extreme limitations of available time and resources, this paper will also attempt an overview assessment of likely impacts of light pollution in the corridor. Finally, it will propose some ideas regarding possible approaches and options to tackling light pollution in the corridor from the technological, social-organizational, economic and cultural perspectives under sustainability aspects. The paper will pay particular attention to the questions of building awareness and community mobilisation, without which no long-term solutions are effectively possible.

Methodology

An extensive literature review was carried out from January to November 2017 focusing on inter- and transdisciplinary sustainability aspects with regards to light pollution, its complex system dynamics and interlinked elements both globally and related to the local perimeter. This covered transdisciplinary\(^7\) scientific research findings, news articles, publications by international, intergovernmental and non-governmental organizations, public administrations as retrieved from the internet, academic literature and articles from the University of Geneva, and workshop presentations. Database searches were retrieved from Google Scholar, ScienceDirect, Elsevier, Springer, PubMed, Artificial Light at Night (ALAN) Research Literature Database\(^8\), with snowball effect of references cited from publications of interest. Search terms used were from the various disciplines relating to light pollution, sustainability and SDG associated targets. The bibliographic references cite the relevant literature found suitable for this study; more exist, which could not be included due to the time limitations of this study.

Despite existing information on light pollution and loss of biodiversity on a global and national scale\(^9\) and from various interest groups respectively, it appeared that hard local data on the many system elements and dynamics was much more complicated to identify and collect. It was therefore crucial to add to the

---

\(^6\) République et Cnaton de Genève, DETA (2015)
\(^7\) Scholz, R. W. (2013)
\(^8\) International Dark Sky Association and Loss of the Night Network (n.d.)
\(^9\) Falchi, F et al. (2016)
Tackling Light Pollution for Sustainability – An Approach for the Vesancy- Versoix Corridor

A literature review a qualitative case study methodology to gather data at local level. Furthermore, the case study methodology focusing on two communities in a cross-border agglomeration setting was chosen as it allowed best to reveal solutions on emergent issues on the topic. The field research consequently included interviews with various stakeholders and some field observation.

Personal open-ended, semi-structured interviews were conducted with officials from the Swiss Cantons of Geneva and Vaud (Nyon Region and Commune de Mies) as well as from the French Commune of Divonne les Bains, the Municipality of the Communes of the Pays de Gex (Department of Ain), the Police force, the French National Forest Office as well as with members of local environmental and hunting associations, all of which are signatory parties to the Vesancy-Versoix corridor contract. Email exchanges and structured questionnaires respectively for data collection purposes supplemented earlier information gathered.

Random open-ended interviews with pedestrians (middle-aged individuals and couples, youths, and seniors of both genders, including both residents and tourists) were carried out within various neighborhoods of the Pays de Gex, Geneva and Vaud at different day and night times during the week to assess the average level of awareness of light pollution, its system dynamics, comfort/discomfort with regards to safety and security and different types of lighting systems. A draft structured survey was produced and tested on a small sample with persons unfamiliar with the issue, which will serve as one of the measures proposed for obtaining further information on people’s attitudes in future. Due to the complexity of the study scope and its limited time frame carried out under the university course, a full-fledged execution and analysis was not possible. However, the feedback received from the sample indicated high interest to the topic. To observe general feedback from the perimeter’s population, we mentioned the research study and some of its specific elements at four public community meetings, a dedicated trans-border workshop organized by local authorities and several associative events, respectively. In June and late October 2017, three separate night field visits were carried out prior to and after 1h00 within the perimeter of the Vesancy-Versoix corridor contract, including the Divonne les Bains and Mies and neighbouring communes for direct real-time observations in an every-day setting.

To build awareness, an original musical-theatrical-poetic performance for the whole family is being organized under this Capstone Project as a potential side event after the European Conference on Energy Transition 2018 in the Greater Geneva region. This involves working with children, adults and regional authorities touching on the topic of reducing light pollution, protecting biodiversity, and reducing energy consumption to support the energy transition to a low-carbon society.

An analysis was carried out using the DPSIR Assessment Framework approach, incorporating a structured presentation of recommendations within the framework of the SDGs.

---

10 Grand Genève (2014a)
11 Our general impression is that most people are very interested in the topic, whether or not being exposed for the first time, and seem to be positively inclined towards the importance of combatting light pollution.
12 Grand Genève (2017)
13 In collaboration with local institutions, the première of “La beauté de la nuit – une comédie musicale du Léman” is in April and May 2018 in the French Pays de Gex performed by over 50 school children, a supporting choir of 20 adults, several instruments.
CHAPTER 2 – A SHORT HISTORY OF SUSTAINABLE DEVELOPMENT

The beginning

The notion of sustainable development itself is often seen as unclear and complex. If sustainable development is to be a useful concept to guide decision-makers and civil society today and in future, it must be clearly defined and understood. In the Middle Ages, legal language already referred to the notion “…Tho trower handt naholden...”\(^{14}\), which we understand as “to hold on trust sustainably for someone”. Because of decreasing timber resources in the 17\(^{th}\) and 18\(^{th}\) centuries – essential to retaining their power – European States learned the necessity to manage their forests well. The word “sustainability” was coined in 1713 by Hans Carl von Carlowitz\(^{15}\) – based on the Latin words reservare (reserve for later), conservare (preserve, maintain), sustenare (hold, support) – and coupled with careful, continuous “use” of resources to ensure sustainable yields in forestry management. Initially, this yield referred to maintaining timber resources per se, but later aimed at maximizing monetary profits.

The triangle of sustainability also first appeared then: environmental equilibrium, economic security, and social justice – influenced, among others, by von Carlowitz’s travels to, and observations of, other States’ perceived best practices, the ravages of the Thirty Years war and the enlightenment philosophy of Spinoza, Leibniz, etc. The environmental equilibrium referred to the generosity and beauty of nature, instilling awe, fostering spirituality and taking nature’s intrinsic value for granted. Economic activities were considered to be founded upon Christian beliefs of working the Earth and taking care of it (Genesis 2,15). From an anthropocentric view, natural resources were perceived as having instrumental use-value for humans. Hence, economics\(^{16}\) – i.e. efficient housekeeping – follows the rational principle that one acts following nature and must not consume more than can be regenerated in future. Sustaining and conserving resources for strengthening the common good is consistent with the social standpoint of pursuing happiness in one’s lifetime (and not in the afterlife), helping the poor and taking responsibility for future generations\(^{17}\). Today’s Oxford Dictionary defines sustainability as the “...avoidance of the depletion of natural resources in order to maintain an ecological balance...”\(^{18}\). While in the 18\(^{th}\) century, European romanticism embraced the above, Adam Smith coupled the principle of universal happiness with the concept of free market forces. The utilitarian approach of the pursuit of happiness referred to natural resources for commercial use, and the highest level of happiness was reflected by the highest monetary figure\(^{19}\).

The industrial revolution was the basis for increasing material wealth in Europe and North America, and later elsewhere. While life expectancy went down in the first few decades of the industrial revolution, it went up with medical innovations and social programmes in the late 19\(^{th}\) century onwards. The industrial revolution was also increasingly accompanied by greenhouse gas emissions (from coal and later other fossil fuels) and extraction of resources. This approach – highly detrimental to the environment – was accompanied by colonialism, the destruction of local cultures and the exploitation of

\(^{14}\) Grober, U. (2013), p.117
\(^{15}\) Carlowitz, H.C. von (1713)
\(^{16}\) Etymologically, economics is derived from the Greek word oikos and nemein, i.e. house or household management, which refers to the human relationship between means and praiseworthy ends. See: Leshem, D. (2016)
\(^{17}\) Grober, U. (2013), pp. 118 ff
\(^{18}\) Oxford university Press (n.d.). Sustainability [Def 1.1]
\(^{19}\) Grober, U. (2013), pp. 146 ff
people. In the 19th and 20th centuries – with accelerated technological innovations, two World Wars and economic recession, etc. – social and ecological consciences emerged. In the mid-20th century, multilateral cooperation mechanisms helped countries to better deal with international conflicts, poverty alleviation, stabilizing financial flows and human rights (e.g., the Bretton Woods institutions, the United Nations, and other international organizations and agreements). The huge industrial infrastructure necessary to fight World War II was rapidly redirected at producing consumer goods – first and foremost in the United States and afterwards in reconstructed Europe and elsewhere.

We know today that massive consumer goods-oriented industrialisation has led to serious environmental damages globally, including air pollution, dispersal of chemicals, agricultural pesticides killing beneficial insects and birds, marine oil spills and many others. The oil crisis but also Apollo 17’s “Blue Marble” photograph – the first one of our whole planet Earth taken from space – strongly influenced society and politics in the 1970s, when economist Nicholas Georgescu-Roegen argued, based on the physical concept of entropy, that natural resources were finite, and that their extraction and utilization in economic activities would degrade the Earth’s carrying capacity and eventually lead to the demise of the human population. Similarly, Meadows’ et al. warned in their Club of Rome report “The Limits to Growth” that population growth, advanced technologies, and finite and depleting resources were creating a global system based on unsupportable economic growth rates. It called for a dynamic equilibrium based on profound changes in value systems, consumption and production patterns, and stabilization of the world’s population.

The need for international cooperation

Recognizing the need for international cooperation, the 1972 United Nations (UN) Conference on the Human Environment in Stockholm was the first major conference to address socio-economic, environmental and development issues. Further instruments were created for international cooperation in various dimensions of environmental protection. There were also calls from organizations such as the World Council of Churches (WCC) “...for a just, participatory and sustainable society...” Yet, these approaches clashed with the prevailing individual-centered neoliberal economic doctrine promoting privatization, deregulation, free trade and cuts to social spending as of the early 1980s, which had replaced Keynesian economic policies.

Nonetheless, the international community adopted the World Commission on Environment and Development report “Our Common Future” in 1987, which called for a strategy that combined both development and the environment. Countries agreed to transform the economic and social status quo to create a global society based on an equilibrium between the three dimensions of sustainability:

---

20 Carson, R. (1962)
21 National Aeronautics and Space Administration (1972)
22 Georgescu-Roegen, N. (1971)
23 Meadows, D.L. et al. (1972)
24 United Nations (1972)
25 For example, the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES); UN-Habitat for human settlements and sustainable urban development – to promote socially and environmentally sustainable towns and cities, aiming at providing adequate shelter for all; World Conservation Strategy – to maintain essential ecological processes and life support systems, to preserve genetic diversity, and to ensure the sustainable utilization of species and ecosystems.
26 World Council of Churches (1975)
nature, society and economics. The so-called Brundtland Report defined sustainable development as “...development that meets the needs of the present without compromising the ability of future
generations to meet their own needs...”28 Economic growth for low-income countries was meant
primarily to alleviate poverty and to cover basic needs. Growth in high-income countries was to be
aimed at increasing the quality of life while limiting production and consumption of material goods, in
consideration of ecological boundaries. The social dimension in the report was tied to socio-cultural
values and ethical approaches concerning inter- and intra-generational access to employment, food,
energy, water and other resources. The values were connected to conservation of ecological resources
and shared use of technologies.

The next 30 years brought acceleration in world trade, freer capital movement, more production and
consumption for rapid returns on investment, and more ecological disasters. This was the opposite of
what had been concluded in 1972. It also saw several international conferences on sustainable
development, culminating in Agenda 2030. At the 1992 Rio Earth Summit29, UN Member States declared
the interdependence and indivisibility of the three — Environment, Social and Economic — dimensions of
sustainable development, and that the global economy must aim to satisfy the needs of both present
and future generations30. Economic growth was to include a long-term vision, technology transfer, social
justice for peace, political systems based on citizen participation, and environmental protection and
conservation — including the “polluter pays” principle. Legally binding agreements were later signed,
including the Framework Convention on Climate Change (UNFCCC) 31 aiming to stabilize greenhouse gas
emissions, and the Convention on Biological Diversity (CBD)32 intended to conserve and share equally
the benefits from biological and genetic diversity. Other outcomes were action plans and guidelines like
Agenda 21, the Rio Declaration, and the Statement of Forest Principles, which are non-binding in
international law, with the Commission on Sustainable Development responsible for ensuring follow-up.

The stocktaking of actions, however, has shown that progress on sustainability has stalled for decades.
This has been mainly due to developed countries’ unchanged production and consumption patterns (not
a viable model for the global economy) and shortfalls in financial commitments to support developing
countries33. The summit in Johannesburg in 200234 brought more political discussions. The 2000-2015
period saw efforts to reach the eight Millennium Development Goals for poverty reduction.
Nevertheless, there was continuing loss of biodiversity, the inclusion of negative policies in decision-
making, and limited data collection possibilities 35, 36. Despite some sustainability-related efforts,
scientific data proved in 2009 and 2015 that we had already overstepped four of the nine
interdependent planetary boundaries of the Earth’s system necessary for human survival37.

28 World Commission on Environment and Development (1987)
29 United Nations (1992a)
30 United Nations (1992b)
31 United Nations Framework Convention on Climate Change (1992)
33 European Commission (n.d.)
34 The nexus of water, energy, health, agriculture, biodiversity was discussed. Summit outcomes were not legally binding. See: United Nations (2002)
35 United Nations (n.d.)
36 Pinter, L. et al. (2015)
37 Steffen, W. et al. (2015a)
Forty years after the first calls for economic “degrowth”\textsuperscript{38} to sustain the Earth’s capacity to provide for life, both the first 1992 Rio Earth Summit and the Rio+20 Conference in 2012 pushed instead for a technology-supported green economy\textsuperscript{39} growth approach and a change in the UN’s institutional framework for sustainable development. Rio+20 also launched a consensus-building consultation process for the post-2015 development agenda\textsuperscript{40}.

**Agenda 2030 – Transforming our world**

In 2015, all countries made an unprecedented decision to embark on “transforming our world” with Agenda 2030, an ambitious action plan “...for people, planet and prosperity...”\textsuperscript{41}. It calls for transforming our style of life for the better towards sustainability; it makes balancing the *environmental, social and economic dimensions* a universal responsibility. Implementing the 17 Sustainable Development Goals (SDGs) and their associated 169 targets means collaboration involving everyone\textsuperscript{42}. While the SDGs are not legally binding, annual stocktaking at the international level takes place based on agreed indicators, and governments are accountable towards their citizens on their implementation. It is hence important that national sustainability stocktaking activities are transparent to the wider mass, and that businesses, NGOs and civil society actively participate in partnerships with public administrations so as to avoid ‘business as usual’. This is particularly important for Europe, where the United Nations report an unsustainable resource footprint for the region. This is due to “...the overuse of natural resources and its trading patterns with other regions. Ecological, societal and economic resilience will be negatively affected in coming decades by global megatrends that are largely outside the region’s direct control and influence...”\textsuperscript{43}.

Owing to the interactions amongst SDG-related activities, this three-dimensional balancing is a challenging endeavour. Indeed, some SDG activities can be cancelling, counteracting, constraining, consistent, enabling, reinforcing or indivisible with each other\textsuperscript{44}. To implement the best possible initiatives for long-term sustainability from all three angles, careful assessment of various systems and their inter-dynamics must be considered. And yet, the notion from the Middle Ages – that we faithfully hold in trust something that is of value for others today and in future – remains valid and is extremely important.

It is indisputable that data from science and citizens’ observations show that human impacts on the environment are substantial and unsustainable and are leading to measurable degradations of our planet. Even though this evidence is staring us in the eyes, and has been for some time, it is difficult to understand why those responsible for governance and we, the ordinary people on the street, have not accepted the need for a radical transformation in our behaviours to achieve a sustainable world.

\textsuperscript{38} “...Degrowth means designing economic and business processes independent from growth imperatives. It is first and foremost about becoming growth independent and finding a new equilibrium of prosperity beyond materialism...”. See: Reichel, A. (2017)
\textsuperscript{39} OECD, WorldBank and UN (2012)
\textsuperscript{40} United Nations (2012)
\textsuperscript{41} United Nations (2015)
\textsuperscript{42} This includes the 193 signatory countries, private sector, non-governmental and intergovernmental organizations, scientific institutions, civil society, and the mobilizing of all available resources.
\textsuperscript{43} UNEP/UNECE (2016)
\textsuperscript{44} Nilsson, M. *et al.* (2016)
Sustainable development is theoretically a very simple concept. It is to live in harmony with nature and fellow humans. Many past and present so-called “primitive” societies have applied it, and continue to apply it, successfully. Yet, in our modern society, it appears that we have lost our way. We also do not understand why and how this has happened. In the previous pages, we have glimpsed at some recent attempts – as yet very unsuccessful – to regain our balance. In the following pages, we will review current concepts and approaches to dealing with sustainable development in the modern age. Looking backwards into the past and up to the present is important for understanding the broader context in which our particular issue – light pollution – fits. Light pollution is a very visible manifestation of the ways in which we have ended up doing wrong to nature and to ourselves. It surrounds us every night. Yet its impacts are not well appreciated, let alone understood. It may not appear at first glance to be as important as other better known sustainable development issues, such as climate change and chemical pollution, but – as we shall see – tackling this problem definitely has its place in the scheme of sustainable development issues, many of which are related to light pollution in one way or another.

**Artificial light at night hampering sustainability**

Despite the ubiquity of artificial light on our planet, and that light pollution is the only form of pollution visible to the naked eye from space, it has surprisingly never explicitly been mentioned as an issue to be tackled in any of the measures described earlier in the long history of efforts to promote sustainable development. Humans have had varying relationships with artificial light at night. Creating light from fires and candles was a huge new technology innovation thousands of years ago. So were oil, gas and kerosene lamps, though most people still thought these to be too expensive for private use, and considered moonlight to be sufficient to move about. Culturally, light was used for special occasions and night was perceived differently than it is today. The revolutionary invention of the electric incandescent lightbulb in the 19th century catapulted lighting technology and its required electric power generation into the modern industrialized world. Different lighting applications followed – fluorescent, halogen and LED lamps, and so on – up to today. Thomas Edison not only created the technological elements of his invention; he also ensured the economic basis and the institutional conditions (through power generation and distribution to homes, businesses and factories) to impose his new product, and influenced consumer behaviour through public displays to a large mass of customers. His ambition, entrepreneurship and systems knowledge allowed him to trigger a social transformation.

From an economic perspective, the electric lightbulb became an incubator for more working hours, increased production and consumption, for new technologies, and eventually for 24/7 trade across the globe. Artificial light at night is seen by many as an indicator for economic progress, representing financial wealth and more comfortable urban living. They see any efforts to combat light pollution by reducing, dimming or turning off the lights as moving backwards, away from modernity. Environmental science and policy have not yet managed to convince our populations of the benefits that the dark can provide to society, through nocturnal ecosystem services and by broadening the path to psychological and physical wellbeing and to spiritual development.

---

45 Sironi, H. and L. Weiss (2017)
46 Pestalozzi, N. (2012)
47 Gallaway, T. et al. (2009) finds both population and GDP as significant variables explaining light pollution
48 Mellander, C. et al. (2015)
Tackling Light Pollution for Sustainability – An Approach for the Vesancy-Versoix Corridor

From a **social perspective**, and depending on individual values, motivation, knowledge or experience, some people wish to illuminate more, others less. The former might respond to cultural or individual fears of darkness and the feeling of loss of control or seek freedom to utilise the night as an extension of the day. In this regard, technology may provide both financial profits and appear as a short-term technical “solution” to camouflage the fears. The latter (those who prefer less artificial light at night) may seek to use the night sky for inspiration and for navigation, and for the psychological benefits of discovering freedom, equality and altruism when pondering the pristine night sky or observing nocturnal fauna and flora. Some argue that without artificial light at night (ALN), there is greater gender inequity as women may be less inclined to move about due to feelings of insecurity\(^49,50\). Wishing to change night into day may also reflect the belief that artificial light increases safety and security, without realising that this correlation has not been demonstrated. On the contrary: excessive and unnecessary light can cause accidents and can induce crime. Insecurity may in fact reflect other factors such as one’s own behaviour, perception of neighbourhood, etc.

From an **environmental perspective**, ALN has significant negative consequences for wildlife and plants, altering patterns of behaviour and reproduction, access to and provision of food and habitat, migration, orientation and interspecies dynamics. The systems dynamics of cause and effect, e.g. on the food web, has environmental, social and economic consequences affecting human health and wellbeing\(^51\), food security, poverty reduction, etc.

The concept of light pollution first appeared in the 1970s\(^52\). Over the last decades, scientists have discovered the many detrimental effects of excessive and/or inappropriate ALN on humans and on the biosphere and have issued warnings about the need to reduce and eventually eliminate light pollution. What seemed to support development turned out to be equivocal from a balanced sustainability position. It is hence crucial to ensure that new technologies, production and consumption patterns, and socio-institutional systems related to lighting follow the premise of integrating environmental conservation aspects into, ideally, a strong sustainability approach. We will return below to the SDGs and to the links between these and light pollution.

**The triangle of sustainability – and how it relates to light pollution**

The concept of sustainable development under the SDGs has three dimensions: social, environmental and economic. This can be represented as a triangle\(^53,54\) (see Figure 2), reflecting the tensions and challenges of achieving balanced, long-term, intra- and intergenerational sustainability at local and global levels. Indeed, the importance of each of the triangle’s corners depends on one’s socio-cultural-psychological perception, geopolitical background, understanding and goals. The three dimensions may be ordered differently according to one’s paradigm. Some even argue that the cultural-aesthetic, political-institutional, or religious-spiritual (value-based ethical) dimensions are still missing\(^55\), and that it should thus actually be a “Triangle + ...”.

In this paper, the dimension of **Nature Protection / Environment Conservation** is placed at the top of the sustainability triangle, with **Social Integration** at the lower left side and **Economic Development and Efficiency** at the lower right side, implying a particular order of priority while aiming to attain a point of

\(^49\) Radio Télévision Suisse - RTS (2017)
\(^50\) Culet, J. (2017)
\(^51\) World Health Organization (n.d.)
\(^52\) Cinzano, P. *et al.* (2000)
\(^53\) Munasinghe, M. (2007)
\(^54\) Campbell, S. (2013)
\(^55\) Burford, G. *et al.* (2013)
equilibrium in the triangle’s centre. We consider for our understanding of sustainability that the cultural-aesthetic, political-institutional, and religious-spiritual dimensions integrate both values and ethics within all of the three dimensions.

Nature, the environment and the Planetary Boundaries

Given that human life on Earth – including our economies and the wellbeing of our societies – depends on Nature, encompassing its genetic and functional diversity and its resilient ecosystem services, Nature\textsuperscript{56} is placed at the top of the triangle. Nature is part of the Environment that surrounds us. The latter is “...the complex of physical, chemical, and biotic factors (such as climate, soil, and living things) that act upon an organism or an ecological community and ultimately determine its form and survival...”\textsuperscript{57}. This definition also encompasses humans, their habitat and their activities.

Nature per se does not depend on humans. It has intrinsic value. In the course of evolution, its myriad species creatively adapted and are adapting to natural biogeochemical, climatic and human-induced changes, interacting with and depending on each other to ensure continuous survival. Nature’s open systems dynamics – with its cycles, linear and exponential growths and feedback loops – generally maintain an equilibrium. Resilient ecosystems return to equilibrium after overcoming disturbance. However, nature’s elements may become extinguished when a critical threshold is overstepped.

Ancient and native cultures often (but not always) lived in harmony with nature. Their cultures and religious beliefs recognised their dependence on nature, and consequently involved treating nature with respect and avoided damaging it. This changed when belief systems began to see humans as figures at the top of the pyramid of nature, with unrestricted rights of use over all else. Industrialisation accelerated this process, ushering in an era of mass consumption and exploitation of natural resources. Since the mid-20\textsuperscript{th} century, human activities globally have so extremely changed our Earth and its environment that we are leaving enduring traces in geological deposits. We have entered the Anthropocene, a new geological epoch. Exponential increases in population, land use, economic activity (agriculture, mining, industry, etc.), consumption of energy and materials, transportation and

\textsuperscript{56} Etymologically, Nature has its roots in the Latin word \textit{nasci} - to be born. The definition of nature is “...The phenomena of the physical world collectively, including plants, animals, the landscape, and other features and products of the earth, as opposed to humans or human creations...”. See: Oxford University Press (n.d.), \textit{English Oxford Living Dictionaries} (online), Nature [Def 1] \textsuperscript{57} Merriam-Webster (n.d.). \textit{Merriam-Webster Dictionary.}, Environment [Def 2.a]
telecommunications systems and other human endeavours are creating a “Great Acceleration”\textsuperscript{58}. These constitute grave threats to the long-term continuity of life on our planet.

**Planetary Boundaries**

“Planetary Boundaries” have been identified\textsuperscript{59} for nine critical, interrelated processes and systems that regulate the Earth’s overall stability and resilience: (1) Climate change, (2) Change in biosphere integrity (genetic and functional biodiversity loss and species extinction), (3) Stratospheric ozone depletion, (4) Ocean acidification, (5) Biogeochemical flows (phosphorus and nitrogen cycles), (6) Land-system change (e.g. deforestation and urbanization), (7) Freshwater use, (8) Atmospheric aerosol loading (microscopic particles in the atmosphere that affect climate and living organisms), and (9) Introduction of novel entities (e.g. organic pollutants, radioactive materials, nanomaterials, and micro-plastics).

The above boundaries define “Safe Operating Spaces (SOS)” for the planet in each of these nine areas. The SOS are represented in Figure 3 by the green zones. Beyond each green zone lies a zone of risk and uncertainty (the yellow zone), reaching up to a threshold or tipping point. Beyond this threshold (the red zone), it is estimated that the system degrades to a point where it suffers critical disruption. The SOS boundary gives us time to take corrective action before reaching the threshold and moving into critical territory.

Four of these planetary boundaries are considered to have already been exceeded, namely: loss of biosphere integrity, altered biogeochemical cycles (phosphorus and nitrogen), land-system change and climate change. Therefore, for these four, we are no longer in a Safe Operating Space: action becomes imperative and urgent. The problem is even more critical given that loss of biosphere integrity and climate change are considered to be “core”, the most crucial in the hierarchy of nine boundaries. They alone can bring about a new state for the Earth – as they have over past epochs.

Alongside the other major damage that humans are inflicting upon nature, is the harm created by light pollution, which has an impact precisely on the core Planetary Boundaries that have already been exceeded: loss of biosphere integrity, climate change and – due to the increasing global population and urbanization that are accompanied and even made possible by light – land-system change.

**Loss of biosphere integrity**

The boundary most impacted by light pollution is loss of biosphere integrity. Globally, this boundary is a high-risk zone and has already been grossly overstepped. Thanks to its ecosystem services, biosphere integrity contributes to human life by supporting the production of myriad essential products – including foods, fibers, fuels, construction materials and medicines – and by regulating the climate and the water cycles, protecting against floods, improving air quality and contributing to cultural and individual wellbeing\textsuperscript{60}. Its free contribution of goods and services has been estimated to be, each year, nearly twice

\textsuperscript{58} Steffen W. \textit{et al.} (2015b)

\textsuperscript{59} Steffen W. \textit{et al.} (2015a)

\textsuperscript{60} World Resources Institute (2005)
Tackling Light Pollution for Sustainability – An Approach for the Vesancy-Versoix Corridor

the value of what we humans produce\textsuperscript{61}. Unnecessary and excessive artificial light at night contributes to loss of biological diversity through its many serious detrimental effects on flora and fauna. It is important here to consider that 28\% of vertebrates and 64\% of invertebrates\textsuperscript{62} are exclusively or partially nocturnal, and thus highly sensitive to artificial light at night. Since more than 90\% of animals are invertebrates and 10\% of animals are vertebrates, this means that around 60,4\% of all animals are nocturnal or crepuscular\textsuperscript{63}. A detailed analysis is available in Chapter 3, Table 2.

All of life on earth has adapted over the eons to survive and thrive with the changing rhythm of day and night. With some delayed response, ecosystems naturally accommodate to any changes in habitat and food provision. Scientists are now observing substantial declines in both genetic and functional diversity. The best indicator currently available to gauge the extent to which this boundary is being exceeded is the rate of extinction. The established boundary is: not to exceed 10 extinctions per million species-years (E/MSY). There are now about 1,000 E/MSY across the globe, and rising\textsuperscript{64}. This global rate of extinction per million species per year is 100 times greater than is specified in the boundary. Undoubtedly, this is the result of the multiple human impacts on the environment, of which light pollution is but one.

In their Assessment for the pan-European region, the United Nations report that “...in Western and Central Europe, only 38.4 per cent of the original species abundance remains...”\textsuperscript{65}. It is difficult to assess local data against the above indicator. However, the latest state of biodiversity measured in Switzerland in 2016 was clearly determined as unsatisfactory.

The studies for Switzerland found that there is a clear risk of loss of biodiversity, as it is also the case at the global level. Since land use is one of the main factors affecting biodiversity, the average biodiversity damage potential (BDP) for Switzerland has been estimated at 0,39. To reach the Aichi targets of the Convention of Biodiversity by 2020, Switzerland (and presumably France if we assume similar data) has to reduce the biodiversity damage potential to 0,16\textsuperscript{66}.

The loss and worsening of the quality of natural habitats, greater fragmentation and increased loss of diversity of species are apparent. And yet, the general perception of over 70\% of the population in the country is, surprisingly, that the state of biodiversity is “very good” or “fairly good”. Studies have shown that the Swiss see conserving biodiversity as an essential “duty to future generations”, as a “connection” to nature and its “beauty”, and as a “moral obligation”\textsuperscript{67}. This shows that there is a very large gap between the actual and the perceived state of country’s biodiversity, and with regard to peoples’ intentions.

\textsuperscript{61} République Française, Ministère de la Transition écologique et solidaire (2017)
\textsuperscript{62} Invertebrates are animals that lack backbones. They are key parts of the food chain for vertebrates and humans. See Encyclopædia Britannica (2017)
\textsuperscript{63} Calculation: (0,9 x 0,64) + (0,1 x 0,28) = 0,604, i.e. 60,4\% of all animals are nocturnal or crepuscular.
\textsuperscript{64} Stockholm Resilience Centre (2015)
\textsuperscript{65} UNEP/UNECE (2016)
\textsuperscript{66} Dao, H. et al. (2015).
\textsuperscript{67} Federal Office for the Environment (2017b)
Tackling Light Pollution for Sustainability – An Approach for the Vesancy-Versoix Corridor

The above responses represent some ethical considerations. For example, “duty to future generations” and “moral obligation” refers to the deontological ethical-philosophical model with an ethics of conviction that one is motivated by moral duty in terms of intergenerational justice. It guides and assesses “…our choices of what we ought to do (deontic theories), in contrast to those that guide and assess what kind of person we are and should be (aretaic [virtue] theories)…”\(^{68}\). This is an anthropocentric view, which also considers that all humans and nature have intrinsic value. The “connection” to nature and its beauty refers to the (individual) perception of happiness, which leads us to utilitarianism. The axiom of this ethical approach is that it is the greatest happiness of the greatest number that is the measure of right and wrong, i.e. happiness is the balance of pleasure over pain, giving equal consideration to everyone. In relation of the creation of feelings of happiness that aesthetics of nature and of animals (or the pristine night sky) provide, which makes up part of who we are, we can refer to the Aristotelian school. Here, a successful lifestyle means to live according to the principles of a philosophical ethic and the associated balanced state of mind, which is the ultimate goal of humanity.

There are at least 45,000 known species living in Switzerland, of which 25\% have been subject to risk assessments. Of these, 3\% have already become extinct; 5\% are on the edge of extinction; 11\% are in danger; 17\% are vulnerable; and 10\% are potentially threatened. In total, thus, nearly half of the species studied are vulnerable and face risks to their existence\(^{69}\). These percentages have been confirmed by the 2015 and 2016 studies (see Figure 4).

In France, the data collected by the National Observatory for Biodiversity shows a “…regression of a quarter (-23\%) of bird populations most sensitive to ecosystem degradation between 1989 and 2015; near half (- 46\%) of bat populations between 2006 and 2014. One-third (32\%) of the species assessed in the IUCN-MNHN Red Lists are threatened, from 8\% to 50\% depending on the species groups…”\(^{70}\).

In the Vesancy-Versoix corridor, the relevant data on the types and number of diurnal and nocturnal species is not yet fully known, according to several sources. On the French side of the territory, there is much room for scientific research to determine which species are declining, and their levels of decline (like for the rest of the country). No data\(^ {71}\) is available for our case study (see later) of Divonne-les-Bains. The commune of Mies in Canton Vaud did carry out some sample studies in their natural reserve areas at the lakeside showing an increase in the numbers of birds, but amphibians and insects declined.

Loss of biodiversity results in a substantial loss of valuable ecosystem services:

“…A decline in the state of biodiversity leads to a decrease in those benefits, which translates into high economic costs: In the EU, it has been estimated that the annual cost of ecosystem services that must be compensated as a result of biodiversity losses will reach up to around 4 \% of the gross domestic product (GDP) by 2050. The quantity and quality of the ecosystem services provided in Switzerland are comparable to those in EU countries. Therefore, it can be assumed that non-action would also be much more expensive for Switzerland than the cost of effective protection and promotion of biodiversity today…”\(^{72}\).

\(^{68}\) Alexander, L. and M. Moore (2016)
\(^{69}\) Office fédéral de l’environnement OFEV (2015)
\(^{70}\) Observatoire national de la biodiversité (2016)
\(^{71}\) The timing of this research did not allow analysis of any potential data from observations on bats by the NGO Ligue de protection des oiseaux (LPO) on Mount Mourex, part of the Divonne commune.
\(^{72}\) Federal Office for the Environment (2017a)
Tackling Light Pollution for Sustainability – An Approach for the Vesancy-Versoix Corridor

The biosphere undeniably provides many basic, provisioning, regulating and cultural ecosystem services upon which we humans depend. Destroying these primary resources will lead to very negative consequences and could end up destroying humans themselves.

Yet, the impact of biodiversity loss cannot – and should not – rest solely on quantifiable losses of ecological services, as seen only from the human perspective. Biodiversity loss primarily constitutes a fundamental loss to the planet itself, its richness, its patrimony and its heritage. The utilitarian response cries out for its limitations. The human response must necessarily thus also be moral, ethical: protecting biodiversity has intrinsic value, in its own right.

The limited information available on the actual state of biodiversity has made it virtually impossible to identify with precision the specific causes of its loss, and the extents of their impacts. Amongst the many causes of loss of biodiversity is light pollution. Although research has demonstrated the biological impacts of artificial light at night through a vast number of studies focusing on particular species at given locations, it has as yet been unable to gauge the overall share of responsibility of light pollution for overall biodiversity loss, across species, across ecosystems.

This situation may improve over time. Thanks to data collected with nocturnal orthophotos, geolocation and biodiversity data, Geneva has ongoing research related to identifying nocturnal species of various biomes and their conflicts with light sources. Reducing and avoiding light pollution is in principle straightforward and will contribute to efforts to protect biodiversity and to maintain and develop ecosystem services in the region.

In line with its signatory responsibilities from the Convention on Biological Diversity and aiming to reach the Aichi targets, France and Switzerland claim to be gearing up their actions to protect biodiversity. The Swiss Confederation is strengthening its efforts with implementing a biodiversity strategy and action plan, which also figures in the federal Strategy for Sustainable Development 2016-2019. However, we have as yet seen no explicit measures in any of the international or national strategies (except for the French Grenelle law) aimed at combatting loss of biosphere through the reduction of light pollution.

Land-system change

Land-system change is the second planetary boundary to which light pollution applies. We are already in the zone of uncertainty (with increasing risk), where we can still make the changes needed to avoid overstepping the threshold.

In 2016, France ranked “…sixth among the countries with the greatest number of endangered species, due to the destruction of their habitats, overexploitation of resources, pollution and climate change. As a result, three-quarters of natural habitats are in an ‘unfavorable’ state of conservation. Despite numerous regulatory tools (parks, reserves, Natura 2000 sites, etc.) only 1% of the metropolitan area is today ‘under strong protection’…” The Ministry for Ecological Transition and Solidarity in 2017 stated that France – being a biodiversity hotspot – is actually ranked fifth, with 278 species globally threatened. About “…180 ha of natural and agricultural land (i.e. nearly 250 football fields) are destroyed every day,

---

73 World Resources Institute (2005)
74 République et Canton de Genève, Département de l’environnement, des transports et de l’agriculture (2017a)
75 United Nations Convention on Biological Diversity (2011)
76 Office fédéral du développement territorial (2016)
77 Garric, A. and P. Le Hir (2016)
replaced by roads, houses, activity areas. This equates to about 70,000 ha per year, equivalent to [losing, ed.] the department of the Vendée every 10 years...” 78.

Switzerland is likewise in an unsatisfactory situation regarding the state of its land. Nearly half of its national natural habitat is threatened. Many areas are fragmented, do not exhibit the required buffer zones, and pressure on ecosystems is increasing. The change in land-system use refers to the loss of forested and other natural lands due to agriculture, urbanization and roads. Artificial light at night that comes with (rapid) urbanization, transport and changing patterns of usage of night-time for increased consumption or economic activities, is one of the elements of pressure, though rarely mentioned in strategic official papers. In fact, it could be argued that, without light, humans would be unable to expand their occupation of the land for their own purposes. Thus, light pollution and changes in land use are closely intertwined.

In the temperate biome – where the Vesancy-Versoix (V-V) corridor is found – the established boundary indicator proposes that forested land should constitute ideally 50%, but at least 30% to 50%, of the potentially forested areas. Our estimations based on data retrieved from the Territorial Information System of Geneva (SITG) 79 (see the maps for the two communes in Chapter 4) are that today’s urbanized area in Divonne-les-Bains is around 20% of its total area (including constructed and sports grounds), its agricultural land is about 15%, and its forested land – mostly in non-constructible protected zones on the Jura mountains – is about 65% of its territory. Thus, it currently comfortably complies with this particular planetary boundary. The case of Mies, however, shows a relative balance of 33% for each of these three zones. It is thus decidedly on the lower end of boundary’s recommendation.

Increased urbanization in the V-V corridor area is driven by demography. The growing population of Grand Genève is forecast to reach 1.26 to 1.36 million inhabitants by 2040, i.e. between 25% to 35% more than in 201580,81,82. Necessarily, whether or not people will squeeze into current homes and built-up areas83, there will be an increasing push to extend the human habitat and for changes to land use on both sides of the border. This change in demography will continue to lead to increases in construction, infrastructure, traffic, landscape fragmentation, etc. and with it an expanding lighting footprint. This means that natural areas, biodiversity and ecosystems are effectively very much under threat, even more than one would perceive (as there is no statistical data on loss of the biosphere). The risk of more landscape fragmentation is high. Things will progressively get worse as urbanization continues apace, unless preventive measures are rapidly put in place. Even without other factors (e.g., climate change and projected significant loss of coniferous forests in the next 20 to 30 years84) accelerating the unprecedented rate of extinction of species, these developments risk a significant likelihood of loss of biodiversity and of damage to ecosystems. The expanding footprint of light will only make matters worse, unless the Franco-Swiss communes decide to implement measures to restrict light pollution.

78 République Française, Ministère de la Transition écologique et solidaire (2017)
79 Service de géomatique et de l’organisation de l’information (n.d.)
80 Mabut, Jean-François (2016)
81 Office cantonal de la statistique (2016)
82 Authorities in the Pays de Gex aim at reducing new arrivals to 120.000 to 150.000 by year 2030, as per statements by the CCPG President at a public consultation, Divonne-les-Bains, 07.03.2017.
83 Di Stefano, L. (2016)
84 The prediction of German foresters (see U. Grober (2013)). also applies to French forest management since both countries are within the same biome of temperate broadleaf and mixed forests, have approximately the same forest cover percentages and management techniques. Therefore, public authorities in the Vesancy-Versoix corridor might consider mitigation measures in due time, if not already done so.
Tackling Light Pollution for Sustainability – An Approach for the Vesancy-Versoix Corridor

Even though this study analyses only a small local area, a wider spatial and long-term vision is needed. The larger the land area being considered, the greater the variety of species it contains, which means better resilience to pressure. Ergo the smaller and more fragmented the area, the quicker the decline in the number of species, the higher the loss of resilience, the higher the risk of extinction and the higher the social, economic and environmental costs from loss of ecosystem services. Therefore, we can only assume that – as the cross-border V-V corridor is small and fragmented – the biodiversity situation is likely to become worse than for the overall situation in the two countries that it straddles. Indeed, previously unknown features in species have been sighted which are possibly signs of in-breeding caused by constrained and fragmented ecosystems. Exotic invasive species further threaten the already pressured local species.

To better implement biodiversity-enhancing strategies, public authorities in the V-V corridor will need to continue to ensure and increase free movement of species not only within the local perimeter of public and private properties, but also across over into national and continental biological corridors. These will integrate biomes of adequate size and buffer zones to satisfy the needs of both different diurnal and nocturnal species.

Furthermore, rural, sub-urban and urban areas with their respective infrastructures rapidly need to provide ecological supportive habitats as part of their land-use plans. This will require, e.g. setting-up transdisciplinary cross-border focus groups to implement specific projects, awareness-raising of already existing protection and conservation efforts, and providing incentives for broadening citizens’ responsibility. Tackling light pollution will need to be a key component of these efforts.

Climate change

Land use change impacts on climate change by reducing the role of forests as carbon sinks and by expanding lands where humans carry out activities that involve the use of fossil fuels that result in CO₂ emissions. Climate change is another of the planetary boundaries with an increasing risk of overstepping the threshold.

Light pollution contributes to climate change due to its inherent excessive use and waste of energy, which – if generated through the use of fossil fuels – unnecessarily increases greenhouse gas emissions (GHG). Light pollution at best serves no purpose, and at worst creates much harm, and yet we spend enormous amounts of energy in creating it. The International Energy Agency (IEA) has estimated that artificial lighting consumes 19% of total global electricity, accounting for greenhouse gas emissions of 1,900 Mt of CO₂ per year, which was the equivalent to 70% of the GHG emissions from the world’s light passenger vehicles. According to Scientific American in 2012, “…the federally-funded National Optical Astronomy Observatory (NOAO) reports that poorly-aimed, unshielded outdoor lights waste $2 billion (17 billion kilowatt-hours) of energy in the U.S. each year…” The International Dark Sky Association

---

85 Hadly, E., Stanford University (2016)
86 A white deer was found in the Versoix forest, and nobody knows how this came about. The author believes that the white fur is a result of genetic modification due to in-breeding, as with white in-bred tigers in zoos (see E. Hadly, Stanford University). This is even more likely as some time ago, a small number of deer were introduced from the hunting reserve in Chambord, France. Due to the non-existence of natural predators, their numbers rapidly increased. However, access to migration routes and diversity in genetic exchange appear to be difficult. See: DETA website Canton de Genève or mag – 20 min.ch (2016).
87 Combatting exotic invasive species is one of the action items of Geneva’s strategic Cantonal Climate Plan. See : République et canton de Genève (2015), Plan climat cantonal-volet 1, p.30
88 Intergovernmental Panel on Climate Change - IPCC (2014)
89 Höllker, F. et al. (2010)
(IDA) estimates that at least 30% of all outdoor lighting in the U.S. is wasted, representing “...up to $3.3 billion and the release of 21 million tons of carbon dioxide per year.”91.

The annual consumption of artificial light over the last 200 years by a typical (English) person increased by a factor of 12,000, while the household expenditure for lighting decreased. There is globally uneven distribution of artificial light and energy consumption. With economic development and despite energy-efficient technology trends, demand for artificial light is estimated to be 80% higher by 2030, notwithstanding unequal distribution between countries and regions. The IEA’s global projections of 2008 were that, without improving energy-efficient policies and technology, the electricity demand for lighting would reach 4,250 TWh by 203092, equivalent to nearly twice the output of all modern nuclear power plants. Further projections were that “...lighting-related annual CO₂ emissions will rise to almost 3 gigatons by 2030...” 93. Over the last decade, we have already seen with the rapid development in more energy-efficient and low-cost new technologies, an increase of up to 90 % in artificial light at night alongside an increase in both energy consumption and CO₂ emissions. To this, imagine the increase in demand for energy and CO₂ emissions when developing countries will be as energy hungry for their economic development as today are the developed countries. And energy demand is soaring for multiple reasons, often related to the use of information technologies. Cryptocurrency operations in Iceland, for instance, already consume more power than all households in the country. 94

In France, artificial light at night has increased by 94% since 1990 95. According to the Association nationale pour la protection du ciel et de l’environnement nocturnes (ANPCEN), the amount of energy spent in 2012 for public lighting was 5.6 billion kWh (without calculating the cost of installation, operation, maintenance, collection and recycling96). The consumption of electricity for illuminated advertisement was 2 billion kWh. Furthermore, 42 % of the electricity spent by the communes was for public lighting97. ANPCEN refers to ADEME and EDF estimates that 30–40% of energy is lost to communes due to bad quality or excessive lighting. The French Association for Lighting (AFE) states that of all the consumption of electricity for public lighting in the country, 23% is by communes98. AFE also indicates that the annual total production of CO₂ from public lighting is 85,000 tons - 800 times less than the equivalent of French car travel, but this was low because of the country’s reliance on nuclear energy. Total energy savings are mentioned as 50–75%. Although the bulk of the electricity in France is still today generated by nuclear plants (with efforts to move to renewable energy sources under the Energy Transition Act), in Switzerland around 60% of electricity consumed is generated from fossil fuels99.

Indeed, artificial light at night in Switzerland recorded an increase of 70% since the 1990. Forecasts made in 2016 by Dark Sky Switzerland based on the Falchi et al. New World Atlas of Artificial Night Sky Brightness state that the total amount of light pollution of 2015 in Switzerland would be double if the external lights were converted to neutral-white light emitting diodes (LEDs)100. Taking as an example the Canton of Geneva, nearly 20% of electricity consumption is spent on public lighting. According to the energy provider Services industriels de Genève (SIG) – supplying nearly 95% of its energy from renewable

91 International Dark Sky Association (n.d.). Light pollution wastes energy and money
93 IEA (2008), op. cit.
95 Gamberini, G. (2016)
98 Association française de l’éclairage (n.d.)
99 Longet, René (2017), p.48
100 Falchi, F. et al. (2016)
energy sources – savings of 50% to 60% could be made if, for instance, illuminated advertisements were to be shut-off from midnight to 6a.m. 101.

Most of the energy wasted in light pollution is generated through fossil fuels, depending on the location. This contributes to GHG emissions, which are the main source of climate change. Efforts to reduce light pollution will thus positively affect GHG emission reductions and help reduce the extent of climate change. This is less true (as we have seen) for countries such as France and Switzerland where most energy for electricity is generated through nuclear and hydroelectric power 102, which themselves also have environmental consequences (e.g., on the Planetary Boundary concerning “Introduction of novel entities”, specifically nuclear waste materials).

The progressive change to low-energy consuming new technologies – independently of any effect on light pollution and human health – is already cutting down significantly on energy use for lighting 103. Some lighting technologies also make it more feasible to apply adaptable and “intelligent” lighting systems (involving timing and movement controls, dimmability, etc.) and – because of its low energy requirement – to use solar panels to power autonomously functioning light poles. These features can in principle reduce the demand for energy and its cost from any fossil-fuel powered grids. However, the low consumption costs of light emitting diodes (LEDs) has also created a “rebound” effect 104, where more lights – with greater luminosity – than actually needed are installed because they cost less to run. This needs to be avoided to maximise the GHG benefits of the new technologies.

Social integration and human needs

This second dimension of sustainable development involves achieving harmony among individuals and meeting their basic needs within the context of social systems. Manfred Max-Neef has identified nine fundamental, simultaneous, complementary and finite human needs that are common across cultures and generations, and that need to be addressed through sustainable development efforts 105. These are: subsistence, protection, affection, understanding, participation, leisure, creation, identity and freedom. Achieving these needs encompasses, amongst others, issues such as respecting all aspects of human rights, inter- and intra-generational solidarity, social equity, poverty reduction, respect for culture,

101 Tribune de Genève (2016)
103 As LEDs consume less energy and thus cost less to use, they are creating a perverse “rebound” effect, where more lighting is installed or environmentally disturbing technology used (for example, LEDs over 4,000 kelvin) because it costs less in energy consumption, and making light pollution worse.
104 Frondel, M. (2012)
105 Max-Neef, M. (1992)
Tackling Light Pollution for Sustainability – An Approach for the Vesancy-Versoix Corridor

physical and mental health and safety, education and empowerment, people’s involvement in decisions that affect them, transparent governance and the rule of law.

Social integration – as described above – relies on a harmonious relationship of people with both nature and technology. Several of these needs – e.g. subsistence, protection, understanding, leisure – often depend on connecting with nature, e.g. for the provision of food and shelter, creating an attractive living environment, access to natural health cures, communing with nature, learning about the world around us, appreciating landscapes, developing curiosity and imagination, running risks and building awareness, etc.

A healthy natural environment is essential for social health. Depletion of resources (particularly water and food), contamination, land degradation, destruction of forests and loss of biodiversity have direct impacts on social conflict, migration and chaos. History shows examples of the downfall of cultures due to over-exploitation of natural resources, including the Mayan civilisation\textsuperscript{106}. Today, competition for dwindling key survival resources such as access to freshwater is the source of many conflicts. In the Vesancy-Versoix corridor, recent years brought several droughts, impacting on local ecosystems and partly changing biomes (e.g. dried out waterways, ponds and marshlands in Divonne les Bains). It might be prudent to assure on a long-term basis that free, safe and equitable access to freshwater for its population prevails within the whole of the corridor perimeter. In short, the Nature component of the sustainability triangle is essential for the Social component to survive and develop.

Regarding the question of light pollution and social integration, using artificial light judiciously can have a positive effect on security, health, learning and going about daily life. On the other hand, unnecessary and excessive artificial light at night can damage people’s health, compromise security, make moving about (e.g. driving) dangerous. It can also make communing with nature and appreciating the full beauty of the night sky as a source of aesthetic pleasure, serenity, joy, awe and inspiration difficult, if not impossible. In this regard, it is important to take account of the “shifting baseline”: as new generations grow up with less and less access to nature and to the night sky, the less they can know what they are missing. This calls for careful management of the “common good” and ensuring that we do not deprive future generations of valuable existential experiences still available to us today.

More information on the impacts of light pollution on peoples’ physical, emotional and spiritual wellbeing is provided under Chapter 3.

The economy and weak vs. strong sustainability

The economy fundamentally aims to improve human welfare by providing goods and services. Preserving nature often seems to be at odds with economic growth, because they both compete for natural resources. Furthermore, economic activity often creates pollution that damages nature and the environment. Resource depletion and pollution from economic activity significantly impact upon biodiversity and ecosystems’ resilience – both directly and indirectly (e.g. through climate change).

The traditional model of economic development – based primarily on the market economy to produce goods and services for consumers – has relied strongly on the extraction of raw materials, energy and other inputs from nature. Processing these materials has created huge quantities of pollution, and of waste at the end of product life-cycles. The industrial revolution, colonization, and later the enormous industrial capacities created for and after World War II, caused speedy acceleration of this process. Over

\textsuperscript{106} Atkins, P.J. et al. (1998)
the last decades, as less advanced countries have sought to develop and grow economically using the same market-based model, the impact on the environment has become more and more unsustainable.

In short, development has become synonymous with economic growth, however destructive this may be. This has been reinforced by global trading and financial systems promoting flows of goods and monetary capital across the planet, the prime motivation being short-term profit and accumulation of wealth.

A report in 2009\textsuperscript{107} estimated that 75\% of the land surface of the planet was subject to measurable human pressure. The highest pressures were found to be in areas with the highest levels of biodiversity. The findings revealed that increases in human pressure were highest for countries with low-middle income levels – given that these are where less-regulated resource extraction efforts are concentrated – and lowest in the high-income countries. Much of the pressure in lower-income countries is also due to economic inefficiencies and to international trade: high-income countries transfer an important part of their human pressure to other countries through their imports – particularly of raw materials, energy and consumer goods.

Switzerland is a good example of this. Its imported consumption-based impact on the environment has been steadily increasing; it now stands at more than twice the level of the country’s domestically-produced consumption-based impact\textsuperscript{108}. “…Almost 50\% of its carbon footprint, 70\% of its material footprint and 90\% of its land footprint are embodied in imports…”. To reach an environmentally-sustainable level, Switzerland’s overall environmental impact\textsuperscript{109} – the outcome of its untenable production and consumption patterns – needs to be reduced by at least half. The situation is similar in France\textsuperscript{110}.

The question thus arises: how to make the economy sustainable? There are two approaches to answering this question: strong sustainability and weak sustainability.

In economic terms, the three elements of the Sustainability Triangle can be seen as different forms of capital: Natural capital (i.e. all of nature’s resources, in terms of valuing ecosystem services\textsuperscript{111}, but not necessarily with reflecting non-anthroposophic intrinsic value); Social capital (i.e. people resources, accounting for their levels of wellbeing, education, skills and productivity, etc. together with the efficiency and effectiveness of their social institutions and related arrangements); and Economic capital (i.e. manufactured or reproducible resources such as built infrastructure and man-made goods and services).

The concept of strong sustainability\textsuperscript{112} attaches unequivocal priority to Natural capital. It considers the elements of nature to be unique and essential, possessing intrinsic value and irreversibly lost if destroyed, and thus attributes the highest precedence to its preservation. Nature’s resources must only be used where they can be regenerated. Strong sustainability is thus nature-centric: it highlights strict limits for employing Natural capital that must not be crossed and requires constraints on human consumption. Consequently, it attaches lower priority to Social and Economic capital regarding access to resources.

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{strong_sustainability.png}
\caption{Strong sustainability}
\label{fig:strong_sustainability}
\end{figure}

\begin{flushleft}
\textsuperscript{107} Venter, O. \textit{et al.} (2016)
\textsuperscript{108} Frischknecht, R. \textit{et al.} (2014)
\textsuperscript{109} Federal Office for the Environment (2014)
\textsuperscript{110} Tukker, A. \textit{et al.} (2014)
\textsuperscript{111} Lovins, A. \textit{et al.} (2007)
\textsuperscript{112} Organisation for Economic Cooperation and Development (2015)
\end{flushleft}
Tackling Light Pollution for Sustainability – An Approach for the Vesancy-Versoix Corridor

Strong sustainability can be illustrated through a series of three concentric circles at different levels (Figure 6). Here, economic sustainability is embedded within, and serves, social sustainability; and both must operate within the framework of an outer circle representing a sustainable natural environment.

Weak sustainability, on the other hand, is anthropocentric: it considers the three forms of capital to be substitutable as long as the total end value for humans is increased. It places no limits on the use of Natural capital, and thus does not recognise the Planetary Boundaries per se. Its approach to sustainability is to improve economic efficiency and minimise the use of resources, but it does not question or challenge consumerism.

Some see the possibility of combining both approaches113, by applying strong sustainability to any attempt to cross over the Planetary Boundaries, while allowing weak sustainability to apply, as long as we are still within the Safe Operating Space (SOS), for example, Switzerland uses approaches “in between” the weak and strong sustainability concept114. It is argued that the SOS can be extended over time – perhaps even indefinitely – through innovative technologies and other mechanisms (e.g. pricing) that increase economic efficiency and reduce resource utilisation. This requires that: (a) value is attached to the environment (e.g. ecosystem services115); and (b) that there is an accounting system in place to monitor the state of this valuation as is being used in ecological economics116. Market-based incentives could then be applied to promote “real” green technologies by (a) requiring end products and services to incorporate the cost of environmental externalities, and (b) supporting green-oriented public investments, research and development, and intellectual property protection.

Other complementary approaches are proposed – and being implemented – to make the economy “greener”, based on the principles of Prevent, Reduce, Reuse and Recycle. Among these is the so-called “circular economy” and the “functional economy”, where “eco-design” ensures – from the very beginning – minimum material use and that the waste from one cycle is used as an input to subsequent cycles, minimising the need to draw non-replaceable resources from nature. This includes reuse, reconditioning and repair of goods already in circulation, as well as – at the end – the recycling of materials into new production processes and returning to nature the materials (e.g. organic) originally taken from it.

The so-called “Sharing economy” is another complementary approach. It encourages consumers to, e.g.: co-purchase goods and services, share what they have purchased with others (e.g., sharing a lawn mower with neighbours), and to purchase services (e.g. mobility) rather than the goods themselves (e.g. cars). Efficient mechanisms are also established for buyers to easily resell to others items no longer needed, to avoid discarding them.

Additional mechanisms to “green” the economy include, e.g.: “do-it-yourself” kits allowing users to assemble the goods they need themselves, thus saving in purchase, transport and packaging costs and their environmental impacts. Relatively recent 3-D printing technology, supported by CAD software, allows users to have their own stocks of raw materials (e.g. powdered plastics, metals, even organic materials) and to “print” products instead of buying them. This technology is particularly useful – from a user’s perspective – for designing (including co-creating) and producing one-off customized products that meet specialised needs and reproducing spare parts (which may no longer be available on the

---

113 Barbier, E. & J. Burgess (2017)
115 Daly, H. (1990)
market) needed to repair equipment. This avoids the need for energy- and material-intensive supply chains to obtain needed goods, while providing flexibility and short lead-times.

On the financing side, crowdfunding/participative financing is being used to finance “green” projects that otherwise cannot obtain funding from the traditional banking system.

These approaches are useful to greening the economy, but achieving strong sustainability is likely to be achievable only through profound changes in consumer behaviour and market organisation. These may include integrating Karl Polanyi’s economic concepts of reciprocity, constraining growth, restricting goods and services that have an unacceptable environmental impact (e.g. luxury items) and organising decentralised, mostly self-reliant but collaborative and networked eco-regions with “…local currency systems, food co-ops, micro-enterprise, farmers’ markets, permaculture, community supported agriculture (CSA) farms, car sharing schemes, barter systems, co-housing and eco-villages, mutual aid, home-based production, community corporations and banks, and localist business alliances”.

Aforementioned are examples for the social and solidarity economy (SSE), a “…concept that refers to enterprises and organizations, in particular cooperatives, mutual benefit societies, associations, foundations and social enterprises, which specifically produce goods, services and knowledge while pursuing economic and social aims and fostering solidarity…”, including social finance.

Concepts of continuing economic growth and of material wealth being the source of happiness would be abandoned, and replaced by attention to deeper human needs, e.g. as described by Max-Neef. In this regard, using the Genuine Progress Indicator (GPI) as an indicator to replace Gross Domestic Product (GDP) for economic development is an alternative. The GPI would increase, for instance, with preserving forests, wetlands and farmland, with shorter transport routes, a higher share of renewable energy, etc. Several US States have adopted the GPI in their policy setting already. At the same time, poverty reduction would still need to be a highest priority, given that environmental degradation takes place where poverty is highest. All of this will require a radical change in peoples’ values, attitudes and lifestyle.

With regard to tackling light pollution in the context of the options described above, “greening the economy” approaches (i.e. weak sustainability) could generally involve looking into the full costs of light pollution and the costs of reducing it – including of wasted energy and climate change, resource depletion, accidents, crime, impacted health, aesthetic loss of the night sky with consequent impacts on spiritual health and creativity, loss of multiple biodiversity ecosystem services, and the cradle-to-grave/cradle-to-cradle life-cycle assessment costs of current and alternative new non-polluting lighting systems. This approach would lead to decisions on the most cost-effective new lighting systems to be implemented, and on ways to implement this that optimise social and environmental wellbeing. This still allows the environment to be degraded and, hence, represents a risk to humanity over the long term.

A more profound, i.e. strong sustainability, approach to the problem of light pollution from all forms of outdoor artificial lighting at night (e.g. street lighting, residential and commercial outdoor lighting, etc.) could involve, for instance:

(a) Using life-cycle environmental impact analysis to determine the best lighting location and features. This would involve preventing and radically eliminating light from where it is not needed, and ensuring that the amounts, locations and timings of light provided correspond precisely to actual

---

118 Scott Cato, M. et al. (n.d.)
119 International Labour Organisation (2011)
120 McGuire, S. et al. (2012)
needs (taking account of environmental conditions and the social variations of people concerned, such as age, gender, health, handicaps, education and skills, etc.). It would also mean avoiding lighting altogether wherever this may impact on natural ecosystems (“dark corridors”), including closing of rural roads near natural areas from dusk-to-dawn to all but local resident traffic.

(b) Ensuring that the selected emissions for lighting systems (i.e. wavelength, colour and “warmth”) give absolute priority to minimising light pollution and its environmental impacts (e.g. on biodiversity, human health, energy consumption and GHG emissions, etc.).

(c) Allowing only for eco-designed121,122 lighting systems that (i) minimise material use and do not draw non-renewable resources from nature, (ii) can be made using local materials, (iii) are pollution- and waste- (especially toxic waste-) free (e.g. are recyclable and, to the extent possible, even compostable), (iv) are based on flexible, modular DIY kits that are easy to install and to maintain locally, allowing for changing components rather than the whole when needed, (v) are off-grid, autonomously powered by renewable energies (e.g. solar and wind), thus avoiding the need for cabling and digging up of streets, and (vi) employ “intelligent lighting” techniques allowing light to adapt (through dimming, on-off and eventually spectrum changes) to the changing astronomical calendar, time of day, weather conditions, security requirements, wildlife movements, movements of individuals and vehicles, and special needs (e.g. the presence of disabled persons).

(d) Extending lighting system life cycles almost indefinitely through local production of spare parts and components (e.g. using local workshops and 3-D printing).

(e) Creating local “lighting cooperatives” within communities and neighbourhoods, where lighting systems are community-owned and where members share in lighting decisions and collaborate in design, financing, production, installation, maintenance, reuse and recycling, etc., thus generating local jobs while also providing local training for relevant sustainability-based knowledge and skills development.

Such approaches to lighting systems would need to be integrated into overall infrastructure development strategies, including decentralised renewable energy generation, housing and road network development, private and public transport-based mobility, etc.

Placing ethics at the centre of economic policy and practice is essential. While cost and financial benefit considerations have a role to play, decisions would need to be firmly based on higher-level objectives relating to protection of nature and to the wellbeing of people and of society. These principles need to be applied to lighting systems as much as to all else.

CHAPTER 3 – SDGS AND LIGHT POLLUTION

This review of the interlinkages between light pollution and the Sustainable Development Goals (SDGs) uses Weitz’ et al. systemic and contextual priority setting approach123, which involved analysing 34 targets out of the total 169 SDG targets and mapping out their cross-interactions. The targets chosen were considered the most relevant for the SDGs in the context of Sweden. Through network analysis, the authors identified their interlinkages and quantified their degrees of mutual influence based on the seven-point typology of SDG interaction scoring124. For each target, first-level interactions (target A

121 Eco-design products and services belong to the functional service economy. See: Stahel, W. (1997)
122 Products from High-level Functional Economy business models with a positive impact on environmental performance. See Bisiaux, J. et al. (2014)
influencing target B) and second-level interactions (target A influencing target B which also influences target C) were scored. The purpose of this analysis was to help policy-makers to establish priorities for effective actions when pursuing sustainable development.

Given that this level of analysis is the only one available, and France and Switzerland – despite their differences – are relatively comparable with Sweden being high income countries in Europe with similar habitat types (biomes) and other indicators, this paper applies the above analysis to the Greater Geneva region. Out of the 34 targets, 13 targets considered to be either impacted by or impacting upon light pollution were selected. The sums of the degrees of influence for each of these 13 targets in the original matrix have been maintained because they reflect the extent of the relationship of these targets to sustainable development overall. The higher the horizontal sum in the table below, the greater the influence of the corresponding SDG target on the other original 33 targets. The higher the vertical sum, the more the target is influenced by these other targets.

A personal assessment was made of the extent of impact of light pollution on these 13 targets as well as of the impact of the 13 targets on light pollution, based on a review of the relevant literature as explained below. The impact ratings chosen were: High (H), Moderate (M) and Low (L). The results are shown on the table 1 below.

Table 1: Impact of light pollution on selected SDG targets, and impact of selected SDG targets on light pollution

<table>
<thead>
<tr>
<th>Impact of LP on target</th>
<th>Influenced: SDG TARGETS</th>
<th>Influenced:</th>
<th>2.4</th>
<th>3.4</th>
<th>4.4</th>
<th>6.6</th>
<th>7.2</th>
<th>7.3</th>
<th>9.4</th>
<th>11.1</th>
<th>11.2</th>
<th>12.5</th>
<th>15.2</th>
<th>15.5</th>
<th>16.6</th>
<th>Sum</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>H</td>
<td>Food production/ agriculture</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>23</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H</td>
<td>Non-communicable diseases</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4</td>
<td>13</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H</td>
<td>Technical/vocational skills</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>30</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H</td>
<td>Water-related ecosystems</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>9</td>
<td>12</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hi</td>
<td>Renewable energy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>12</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hi</td>
<td>Energy efficiency</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>20</td>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L M</td>
<td>Infrastructure/clean technology</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>28</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L H</td>
<td>Affordable housing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>13</td>
<td>9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H H</td>
<td>Transport</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>21</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H</td>
<td>Waste</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>29</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>Forests</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>12</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H</td>
<td>Biodiversity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>16</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>H</td>
<td>Effective institutions</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>51</td>
<td>1</td>
</tr>
</tbody>
</table>

Legend – Typology of SDG target interactions

- Cancelling (-3). Makes it impossible to reach another goal
- Counteracting (-2). Clashes with another goal

<table>
<thead>
<tr>
<th>Abbreviations</th>
</tr>
</thead>
<tbody>
<tr>
<td>LP Light pollution</td>
</tr>
<tr>
<td>H High impact</td>
</tr>
</tbody>
</table>

125 WorldBank (2017)
Tackling Light Pollution for Sustainability – An Approach for the Vesancy-Versoix Corridor

<table>
<thead>
<tr>
<th>Constraining (-1). Limits options on another goal</th>
<th>M</th>
<th>Moderate impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consistent (0). No significant positive or negative interactions</td>
<td>L</td>
<td>Low impact</td>
</tr>
<tr>
<td>Enabling (+1). Creates conditions that further another goal</td>
<td>Hi</td>
<td>High impact with inverse relationship</td>
</tr>
<tr>
<td>Reinforcing (+2). Aids the achievement of another goal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Indivisible (+3). Inextricably linked to the achievement of another goal</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Adapted from “Towards systemic and contextual priority setting for implementing the 2030 Agenda”, Wietz, N. et al. (2017)

The reasonings behind the various H/M/L impact ratings applied above are outlined in Table 2 below. The ratings in the first column reflect the extent to which reducing light pollution will have a positive effect on achieving the corresponding SDG target. The ratings in the second column reflect the extent to which achieving the corresponding target will impact on light pollution. The above table allows us to appreciate not only the direct impacts of / on light pollution in relation to these 13 individual SDG targets, but also the indirect (or second-level) impacts of light pollution through the cross-impacts amongst these targets. For instance, light pollution impacts directly upon food production / agriculture (2.4) and upon biodiversity (15.5). However, its direct impact upon biodiversity also creates a supplementary indirect impact upon food production / agriculture.

Table 2: Reasons for the H/M/L impact ratings applied to light pollution in relation to the selected SDG targets

<table>
<thead>
<tr>
<th>Impact of LP on target</th>
<th>SDG TARGETS</th>
<th>Reasons for the H/M/L ratings</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2.4</td>
<td>Sustainable food production / agriculture: increase productivity and production, maintain ecosystems, adapt to climate change and...</td>
</tr>
<tr>
<td>H</td>
<td></td>
<td>• Artificial light at night (ALN) has a direct impact on plant phenology, photoperiodism, growth and resource allocation. For instance, it “tricks” plants and trees into budding earlier126,127 and/or holding on longer to their leaves in early winter, which impacts upon their health and resilience and thus also affects any herbivores feeding on them. Artificial light intensity, colour spectrum and exposure are proven to modify growth and nutritional properties of produce131, which needs to be well considered when planning and setting up public lighting.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• ALN in urbanized, sub-urban and rural areas keeps away nocturnal pollinators such as moths and bats from agricultural lands, forests and water-related ecosystems,132 with a knock-on negative effect also on diurnal pollinators, on biodiversity, food security and other ecosystem services. Artificial light is also used as pest control mechanisms,</td>
</tr>
</tbody>
</table>

---

126 Ffrench-Constant, RH. et al. (2016)
128 Bennie, J. et al. (2016)
130 Bennie J. et al. (2015)
131 Chen, X. et al. (2016)
132 Altermatt, F. and D. Ebert (2016)
133 Knob, E. et al. (2017)
disasters, and progressively improve land and soil quality particularly LEDs. However, humans depend heavily on pollinators for agricultural production, food security and nutrition, and will depend even more so in future given the projected increases in global population\textsuperscript{134,135,136}.

- Fish is part of the human diet. If water-related ecosystems are disturbed and not sustainably well managed respectively, food security is unreliable. See also SDG targets on water-related ecosystems (6.6) and on biodiversity (15.5) below.

- Due to the systems dynamics, disturbance of the food producing elements of the system through light pollution can reduce the provision of key ecosystems services.

- Agriculture is concerned with the Aichi Targets of the Convention on Biological Diversity (CBD), which determine the score of the biodiversity limits as 0.16. Switzerland’s 2011 footprint was 1.9 times more than this limit.

<table>
<thead>
<tr>
<th>H</th>
<th>3.4</th>
<th>Non-communicable diseases: reduce by one third premature mortality from non-communicable diseases through prevention and treatment; promote mental health and wellbeing</th>
</tr>
</thead>
</table>
| - Exposure to natural light during the day is important to maintain wellbeing. However, exposure to artificial light at night (ALN) changes the brain and the body’s biological clock since we use light to distinguish between day and night. ALN re-synchronizes related physiological and psychological processes. It affects peoples’ circadian rhythms through melatonin suppression and consequently can negatively impact on sleep cycles, cellular function, gene expression. It can lead to depression\textsuperscript{137} and suicidal behaviour\textsuperscript{138}, immune system suppression, metabolic dysfunction such as obesity, diabetes, cardio-vascular disease, certain cancers\textsuperscript{139} and other non-communicable diseases\textsuperscript{140,141}.

- ALN from blue light LEDs in smartphones, PCs, TV, etc. can cause photochemical damage to the retina of the eye\textsuperscript{142}. While arguments exist that outside lighting would be too far away to create retina damage, some chronobiological research is ongoing to find proof on this subject\textsuperscript{143}.

- Youth in urban areas often experience more ALN exposure than youth in rural areas with above correlation of behaviour. The more ALN shines in residential areas, the later youth will go to sleep. The same correlation exists for evening/late exposure to blue light electronic media (see above). Results are more sleepiness during the day, which has negative effects on academic/school success, drug and stimulants\textsuperscript{144} consumption, health\textsuperscript{145}. Depending on the youth chronotype, there is a correlation

\textsuperscript{134} Potts, S. \textit{et al.} (2016)
\textsuperscript{135} Food and Agriculture Organization (2016)
\textsuperscript{136} Macgregor, C. J. \textit{et al.} (2017)
\textsuperscript{137} Weiber, R. (2015)
\textsuperscript{138} Min, J. and K. Min (2017)
\textsuperscript{139} Stein, A. (2015a,b)
\textsuperscript{140} Haim, A. and A. Zubidat (2015)
\textsuperscript{141} Bedrosian, T.A. and R.J. Nelson (2017)
\textsuperscript{143} Hicks, D. (2017)
\textsuperscript{144} Stimulants, for example, are coffee, alcohol, cigarettes.
\textsuperscript{145} Vollmer, C. \textit{et al.} (2012)
Tackling Light Pollution for Sustainability – An Approach for the Vesancy-Versoix Corridor

regarding un-/healthy food intake, physical activity; and all of the above can be continued as behaviour into adulthood\(^\text{146}\), which burdens public health systems and local economies.

- High-intensity blue-rich LED\(^\text{147}\) outdoor lighting (e.g. 4.000 kelvin) or in cars can create glare that produces discomfort and decreases visual acuity and safety fostering road hazards\(^\text{148}\). Elderly persons – increasing in numbers in the Greater Geneva area – are likely to experience more discomfort and insecurity when exposed to blue light due to decreased lens transmittance. As of 65 years, visual abilities decline concerning perceiving colour contrast, saturation, retinal luminance (½ of a 20-year old), focus at close range and other eye diseases\(^\text{149}\). Public lighting from a sustainability social equity perspective must consider differences in gender and age and major walkways of those concerned. See also Transport (11.2).

- Stargazing appears to be therapeutic. Starlight therapy - artificial display of starlight in a room - to ease anxiety, pain and other symptoms for end-of-life patients was successful within 30 min and provided relief from symptoms up to 2 hours\(^\text{150}\).

- Tourist and wellness/health rehabilitation destinations require public lighting that fosters undisturbed sleep\(^\text{151}\), i.e. light trespass and unnecessary, unused lighting is to be avoided as otherwise it counteracts health rehabilitation efforts.

- 99% of the population living in Europe and in North America live under light-polluted skies and 60% in Europe cannot see the Milky Way\(^\text{152}\). Light pollution diminishes peoples’ wellbeing, a sense of strengthened community connections, humbleness and feeling of awe, serenity and the spiritual uplifting when appreciating the full beauty of the night sky and to commune with nature\(^\text{153}\). It also deters from beneficial and transformative encounters with nature and instead might support egoistic navel gazing and non-collaboration. Feeling of awe that come from pondering starry nights and the universe foster altruistic and positive social behaviour\(^\text{154,155,156}\). The above benefits of closeness to nature via observing unobtrusive night sky relates to all of the nine fundamental human needs identified by Max-Neef such as subsistence, protection, affection, understanding, participation, leisure, creation, identity and freedom\(^\text{157}\).

\(^{146}\) Kohl Malone, S et al. (2016)  
\(^{147}\) Harris, T. and W. Fenlon (2002)  
\(^{148}\) American Medical Association (2016)  
\(^{149}\) Tosini, G et al. (2016)  
\(^{150}\) Emerson, K et al. (2015)  
\(^{151}\) Internet searches lead to many tourism offers, especially related to health, wellness and rehabilitation worldwide using non-polluted skies as tourist attraction.  
\(^{152}\) Falchi, F et al. (2016)  
\(^{153}\) Blair, A (2016)  
\(^{154}\) Piff, PK et al. (2015)  
\(^{155}\) Bergland, C. (2017)  
\(^{156}\) Freeman, S (2015)  
\(^{157}\) Max-Neef, M (1992)
Tackling Light Pollution for Sustainability – An Approach for the Vesancy-Versoix Corridor

<table>
<thead>
<tr>
<th>H</th>
<th>4.4</th>
<th>Technical / vocational skills: increase the number of youth and adults with relevant skills, including technical and vocational, for decent jobs and entrepreneurship</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>• Business opportunities &amp; entrepreneurship related to Dark Sky Reserves and Parks are increasingly attracting tourism and, hence, local income(^\text{158}).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Transdisciplinary environmental knowledge and skills are not sufficiently embedded in traditional and new jobs. Differences and fragmentation of policies, concepts and understanding of green economy / green jobs prevail internationally and nationally. There is no harmonization or interlinkages of environmental and vocational training and TVET for sustainable development. The shortage of skilled labor and gender inequality in technology / IT / natural sciences-specific fields hinders the transition to a green economy(^\text{158}) and sustainable economy centered around environmental sustainability respectively.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Given the dramatic increase in light pollution of 70% over the last 25 years(^\text{160}) with an increase of artificial light at night of up to 20% depending on the region(^\text{161}), potential risks of rebound effect due to less costly technologies and the ubiquity of lighting systems, policy-makers and enterprises need to employ people with the right knowledge and skills to create and implement non-polluting new lighting systems based on sustainability principles and practice.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• All professions require lifelong training and support to integrate sustainability and green skills into existing and newly created jobs together with generic skills (communication, participation, adaptability, systems thinking(^\text{162}), ethics, risk analysis and mitigation, innovation, legal, language, etc.).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Research, policy and practice have to collaborate to find sustainable solutions(^\text{163}).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Only if you are aware of something you can make a change. Being deprived of knowledge and/or not being able to access relevant skills threatens achievement of the common goal to ensure sufficient living conditions on the planet.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>H</th>
<th>6.6</th>
<th>Water-related ecosystems: protect and restore water-related ecosystems, including mountains, forests, wetlands,</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>• Human population is often centred along or close to water-related ecosystems, and our habitat is increasingly filled with ALN.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Light pollution disrupts water-based ecosystems, particularly those within or nearby urban areas. Research has found artificial light at night to inhibit the normal vertical movement of zooplankton from deeper to shallow waters to graze on algae, resulting in excessive algal growth in water bodies and affecting other water-based animal and plant life(^\text{164}).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Research has found artificial light impacting upon stream, riparian and terrestrial ecosystems, and proposes further studies to identify more closely the effects of different light wavelengths(^\text{165}). Research also found correlations with ALN concerning the abundance and composition of emerging aquatic insects, flying insects and night-active ground-dwelling predator</td>
</tr>
</tbody>
</table>

---

\(^{158}\) Internet searches lead to many tourism offers worldwide using unpolluted skies as tourist attractions.\(^{159}\)

\(^{159}\) Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) (2013)\(^{160}\)

\(^{160}\) Knop, E. et al. (2017)\(^{161}\)

\(^{161}\) Hölker, F. et al. (2010)\(^{162}\)

\(^{162}\) Institute for Systemic Leadership (2009)\(^{163}\)

\(^{163}\) Gaston, K. et al. (2015).\(^{164}\)

\(^{164}\) Moore, M. et al. (2000)\(^{165}\)

\(^{165}\) Wheeling, K. (2015)
Tackling Light Pollution for Sustainability – An Approach for the Vesancy-Versoix Corridor

rivers, aquifers and lakes

Light impacts circadian rhythm, reproduction and behaviour of above insects and fish. For example, some fish swim 2 meters higher than normal due to ALN. For some, like eel, light can become a barrier to reach their spawning grounds. Commercial fish farming uses prolonged light exposure that delay salmon and trout in reaching reproductive abilities while fostering body growth\textsuperscript{167}.

Mosquitoes and midges are part of the ecosystem. Research is progressing on the issue that light impacts reproduction, food hunting patterns and genetic architecture modification\textsuperscript{168}. The impact of a changing climate coupled with other environmental stressors onto reproduction and genetic modification is yet unclear.

Increased human population and migration, climate change with raising temperatures, exotic invasive species, more heat waves and other weather patterns will have an impact on freshwater quantity, quality and access for consumption. We assume that adding externalities like too much ALN might result in too much stress for the system to be able cope. Other than common sense and strategic systems thinking, we could, however, not find interdisciplinary scientific research today to prove this thesis.

Water-related ecosystems provide basic, provisioning, regulating and cultural services to humans. Disturbing them to the level that they cannot regenerate means human health and biosphere are negatively affected, which results in economic loss and expensive substitutes\textsuperscript{169}.

H 7.2 Renewable energy: increase substantially the share of renewable energy in the global energy mix

Consumption, distribution and production patterns are part of systems dynamics and have an impact on sustainability. This is also true for renewable energy sources.

Phasing out fossil fuels being substituted by renewable energy sources contributes significantly to reducing greenhouse gas emissions, which is a necessity to mitigate the risk of overstepping the threshold value of the climate change planetary boundary.

With the increase in utility-scale solar energy development (USSED) there is nevertheless a risk of a rebound effect, i.e. that more lamp posts or increased used of shortwave, white-blue LEDs than needed are installed\textsuperscript{170} because they are powered by renewable energy sources and do not involve energy consumption costs.

\textsuperscript{166} Manfrin, A. et al. (2017)
\textsuperscript{167} Leibniz-Institute of Freshwater Ecology and Inland Fisheries (n.d.). SP09
\textsuperscript{168} Leibniz-Institute of Freshwater Ecology and Inland Fisheries (n.d.). SP10
\textsuperscript{169} World Resources Institute (2005)
\textsuperscript{170} Falchi, F et al. (2016)
### Tackling Light Pollution for Sustainability – An Approach for the Vesancy-Versoix Corridor

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>H</strong></td>
<td>7.3</td>
<td><strong>Energy efficiency:</strong> double the global rate of improvement in energy efficiency</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>L</strong></td>
<td><strong>M</strong></td>
<td>9.4</td>
<td><strong>Infrastructure/ clean technology:</strong> sustainable infrastructure and industries through increased resource-use efficiency and adoption of clean and environment-tally sound technologies</td>
</tr>
</tbody>
</table>

- Mitigation measures for USSED have to be considered in terms of ecological impact on ecosystem services and land-use changes to avoid fragmentation of habitat, “…barriers to gene flow, increased noise, electromagnetic field generation, microclimate alteration, pollution, water consumption, and fire. Facility design effects, the efficacy of site-selection criteria, and the cumulative effects of USSD on regional wildlife populations…” likely needs further research.
- New, low-energy consuming lighting technologies are more amenable to be used in connection with autonomous, off-grid solar-/wind-powered lighting applications, as long as these imply a considerable product life time. This increases the share of renewable energies used for this purpose.
- By using renewable energy and reducing energy consumption (see 7.2), significant efficiencies in energy use can be achieved while maintaining or improving the effectiveness of lighting services in terms of meeting real needs.
- Meeting only real needs means providing the sufficient amount of light needed, where it is needed, and when it is needed., thus reducing energy consumption.
- There is a risk of rebound effect (see 7.2), which needs to be recognized and mitigated.
- New lighting technologies such as LEDs, OLEDs, etc. are providing opportunities to substantially reduce energy consumption. However, some generations of LEDs (based on white-blue light spectrum with filters to generate other wavelengths) are creating hazards to biodiversity and human health (see 3.4) and increase light pollution. Changes in light colour spectrum to “warmer” light (longer wavelengths) to reduce impact on the living may, however, might require LED lamps with some higher energy consumption to meet environmental friendly requirements (see 9.4).
- Applying this target to lighting technologies will result in lighting that is more long-term sustainable, pleasing aesthetically and less harmful to the environment – regarding its impact on biodiversity (see 15.5), human health (3.4), renewable energy (7.2), energy consumption (7.3) and its effects on residual waste (12.5). This involves developing and applying: less harmful light emissions; systems for adapting the amount of lighting and its intensity to actual requirements (based on movement and traffic, seasonal and weather conditions, etc.); standalone solar-powered lighting systems; use of less toxic and environmentally impacting materials; and full-scale recycling, etc.
- Regarding the lighting technologies themselves, and considering that the massive change towards using LEDs appears inevitable in the light of their very low energy consumption, it is important to consider the impact of recent advances in LED technology that would appear to promise a significant improvement in its ability to minimise light pollution and reduce its health impacts on humans and on the biosphere. The following is noteworthy in this regard: “…Even the best of these white LEDs create significantly more (2x-7x) sky glow than the high-pressure sodium (HPS) lights that have been common in US cities for decades. Fortunately,

---

171 Lovich, J. and J. Ennen (2011)
172 Frondel, M. (2012)
and processes to mitigate this are available: various types of filtered LEDs that remove emission entirely below 500-550 nm, phosphor-converted amber (PCA), and true narrow band amber (NBA). The PCA LEDs have a mellow amber colour similar to HPS, while NBA is a reasonable spectral analogue for the best dark-sky lighting of all, low-pressure sodium...” 173. Public lighting should be sustainable eco-green174 and take place in stages to allow introducing the best technological option, finding a balance between environmental friendliness, social needs and economic thinking.

- Some LEDs contain rare earths, which are mainly extracted from China, DR Congo, and also exist in Afghanistan. These countries face high environmental degradation and especially the two latter ones are bled by war. We assume that finding substitutes for rare earths or avoiding the dependency from it for electronics and other technologies could eventually loosen the geopolitical conflicts.

- Infrastructure & clean technology involves applying the four sustainability principles175 along a cradle-to-crade based supply chain, thus making it part of the circular economy: (1) not to systematically increase concentrations of substances extracted from the Earth crust; (2) not to systematically increase concentrations of substances produced by society; (3) not to systematically increase degradation by physical means; (4) not subject to conditions that systematically undermine the capacity of humans to meet their needs.

- On the one hand, using smart lighting operations and management systems seem to make sense to better control lighting intensity and timing. On the other hand, a certain amount of energy will be needed to feed into the smart networked installations. If included within the Internet of Things (IoT), the biggest risk is cybercriminals attacking / taking control of the infrastructure. It is likely that cybercriminals would be some steps ahead of cybersecurity and protection mechanisms. Therefore, connecting lighting infrastructure to the IoT has significant risks. Furthermore, today the level of data protection and privacy related to IoT matters is not yet clear.

Affordable housing: ensure access for all to adequate, safe and affordable housing and

- The projected increases in global176 and local populations177, 178, 179 will require safe and affordable housing for different socio-demographic groups. Urban growth (infrastructure and transport) creates the potential for more light pollution, unless sustainable, environmentally- and health-friendly lighting schemes are used.

- Intelligent, time-bound & moderate use of lighting systems in new housing development now and in future can help to reduce the cost of housing, particularly in terms of energy consumption but also residents’

---

174 For green technologies to spur, the costs currently are too high, the risks are too great or the markets are too small. See: de Boer, Y (2016)
175 Natural Step (n.d.)
176 The world population projected to reach 9.8 billion in 2050, and 11.2 billion in 2100. See: United Nations (2017)
177 In 2014, the Greater Geneva region counted 946.000 residents. See : Grand Genève (2014b)
178 In the beginning of January 2017, regional demographical statistics refer to approximately 1 Mio residents. See : Rossier, R. (2017)
179 The demographical projections up to 2040 suggest an increase of 25% to 35 % more than in 2015 with a population of 1,26 Mio to 1,36 Mio. See: Office cantonal de la statistique (2016)
<table>
<thead>
<tr>
<th>M</th>
<th>H</th>
<th>11.2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Transport:</strong> access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| **Fragmentation of habitat is the biggest risk for land-system change (planetary boundary).** Due to road transport, infrastructure and urbanization, land-system changes are increasing globally. This leads to continuous fragmentation of larger and smaller habitat and ecosystems, depriving animals to follow their natural and necessary behaviour and migration routes. Protected biological corridors are needed. The smaller an area, the lower the level of biological diversity, increasing the risk for less resilience to external pressures. |

| **Lighting of streets and roads and the lights on vehicles are a significant source of light pollution. As more roads are built and more lights are installed, and as vehicular traffic increases, light pollution will inevitably also increase unless anti-light pollution measures are adopted.** |

| **Light spectrum and glare can create discomfort and serious road hazards.** The correlation between road security and lighting at night is not clear. Some studies found that lighting can help to avoid road hazards. Some found that lighting has no effect. Some studies found that lighting could be the cause of road hazards, e.g. through speeding, impaired vision through glare or that drivers forget to turn on their vehicle headlamps when the amount of lighting is very high. |

| **Different age groups perceive artificial light at night differently for biological reasons (youth and elderly people have different degrees of sight capabilities) or level of flexibility in moving around (see 3.4), which** |

---

181 ACPO Secured by Design (2011); Department for Environment, Food and Rural Affairs, Government of the United Kingdom (2013)
182 Riggs, M. (2014)
185 Federal Office for the Environment (2017a)
186 République et Canton de Genève (2017b)
189 Jägerbrand, A (2015)
results into varying degrees of comfort\textsuperscript{191}, while the attitude towards fear plays also a role.

- Individual and social psychological factors need to be considered in landscape / urbanization planning and implementation. Depending on exposure to crime, gender, education, social contexts, etc. and on the resulting emotional response to stress factors or to an environment, people perceive safety in public spaces and transport differently at day and night\textsuperscript{192,193}. Lighting plays a role only to a certain extent. Today’s technology allows to balance both the need for control at night to see as during day hours, while ensuring the need for darkness. Social control and civil courage to help one’s neighbour is most important.

- Combatting light pollution can influence how modes of transport are used, providing another reason for using public transport instead of individual cars. This contributes to a low-carbon society since less energy is / fossil fuels from road transport are consumed per person.

- Increase in road accidents in dark areas involving wildlife since, for example, deer cross streets to follow their natural needs in those few dark spaces that are left in the region.

- With the introduction of autonomous self-driving cars and artificial intelligence, probably within the next decade, the need for general road public lighting will cease except for providing for pedestrians, bicycles, and other modes of transport for short or moderate distances.

### Waste:

- 1.0 million metric tons (Mt) of lamps became waste material across the world in 2014\textsuperscript{194}. Excessive lighting – i.e. light pollution – contributed to a substantial part of this waste. As more lighting is installed worldwide in response to growing urbanisation, this will potentially lead to even greater waste. However, newer lighting technologies with greatly increased longevity compared to previous technologies can substantially reduce the amount of waste over time. Light pollution control measures aimed at preventing and reducing light use to only where and when it is needed (e.g. through dimming, use of movement detectors and off-peak shut-offs) will help to further contain and reduce this waste.

- Individuals need to tediously recycle light bulbs as they do not belong to normal household waste\textsuperscript{195}.

- A key issue for different lighting technologies is their overall environmental impact – including the toxicity of their wastes and the extent of recycling. A 2012 study by the US Department of Energy found that the life-cycle environmental impacts of LEDs (covering inputs, manufacture, transport, use and end-of-life) were lower across four areas (resource impacts, air impacts, water impacts and soil impacts) than for compact fluorescent lights (CFLs) and (particularly) for incandescent lights\textsuperscript{196}. The environmental performance of LED technology is expected to improve over time as and when toxic waste

\begin{table}[h!]
\centering
\begin{tabular}{|c|c|c|}
\hline
\textbf{M} & 12.5 & \textbf{Waste:} substantially reduce waste generation through prevention, reduction, recycling and reuse \\
\hline
\end{tabular}
\end{table}

\textsuperscript{191} Jägerbrand, A (2015)
\textsuperscript{192} Fox, K. et al. (2009)
\textsuperscript{193} Condon, S et al. (2007)
\textsuperscript{194} Baldé, C.P., et al. (2015)
\textsuperscript{195} Juergensen, N. (2013)
\textsuperscript{196} U.S. Department of Energy (2012)
Tackling Light Pollution for Sustainability – An Approach for the Vesancy- Versoix Corridor

| M | 15.2 | **Forests:** promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests and substantially increase afforestation and reforestation globally
|---|---|---|
|   |   | • As indicated under 2.4, artificial light at night has a direct impact on tree phenology, photoperiodism, growth and resource allocation, weakening the health and resilience of wild plants and trees.\(^{197,198,199}\) Even though artificial lights are not frequently found within forests, they will nevertheless be found where there is regular human activity at night, e.g. logging, nearby settlements, etc. Forests within the reach of urban sky glow will be affected also by this.
|   |   | • Artificial light at night has been shown to inhibit the role of bats in nocturnal seed dispersal, important for natural reforestation of depleted tropical forests. Slowing this process contributes to soil erosion and the inability to reconnect fragmented forests\(^{200}\).

| H | 15.5 | **Biodiversity:** take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and protect and prevent the extinction of threatened species
|---|---|---|
|   |   | • Numerous studies have documented the negative effects of artificial light at night on plants, animals and micro-organisms\(^{201}\). We have already referred previously to its impacts on plants, trees and pollinators (2.4, 15.2) and on zooplankton and other water-based life (6.6). Over its billions of years of existence on planet Earth, life has relied on the predictable cycles of night and day, across seasons. It influences movement and migration, feeding, resting, protection from predators, nesting and reproduction\(^{202}\). Over the last few decades, artificial light at night has increasingly disrupted this delicate balance, seriously impacting upon the biosphere, including birds, mammals, amphibians, insects and plants, who all perceive light spectrum differently.
|   |   | • There are studies in the Canton of Geneva on the impact of ALN on night active species to try to gage the extent of their sensitivity\(^{203}\). Bat species react differently to different light spectrums and change their travel and feeding behaviour\(^{204}\). Some bats species might congregate closely to certain types of artificial light to follow their prey (the ‘light tolerant ones’), whereas others avoid the light (the ‘light averse ones’). This can lead to higher food competition and scientists conclude that decline in a certain bat species in Switzerland is due to some species taking

---

\(^{198}\) Bennie, J. *et al.* (2016)
\(^{199}\) Ffrench-Constant, R.H. *et al.* (2016)
\(^{200}\) Rowse E.G., *et al.* (2016)
\(^{201}\) Sordello, R. (2017)
\(^{203}\) République et Canton de Genève, DETA (2017b)
\(^{204}\) Baker, J. (2016)
Tackling Light Pollution for Sustainability – An Approach for the Vesancy-Versoix Corridor

advantage of the increased foraging opportunities provided by street lights while those in decline can not\textsuperscript{205}.

- The light intensive urban and suburban areas clearly act as biological sinkholes for some species, e.g. moths and bats that feed on the moths. They are being vacuumed in from natural areas and causing great threats to reproduction and survivability given the absence of nutrient resources in this urban/sub-urban habitat\textsuperscript{206}.

- Bird migration highly affected as birds can become disoriented over highly illuminated urban areas, where they circle too long time and can die. Studies shown that especially searchlight sky beamers / light installations such as the annual fall ‘Tribute in Light’ show to remember Sept.11 attract hundreds of thousands of birds. They become disoriented, some fall to the ground and all lose precious time and energy needed for their marathon migration route south.\textsuperscript{207} Switzerland has already banned sky beamers. However, we do not know the attractiveness of light installations for festive activities such as Les Fêtes de Genève in late summer to birds.

- Change in aviary behaviour such as diurnal birds singing through the night due to ALN, hence, getting less rest needed for a healthy lifestyle. Furthermore, different nesting patterns of being too early or too late in the season and, therefore, risking death of offspring with visible quantitative results in our gardens.

- Larger-sized fauna such as deer and wild boar are no longer present as in the past, due to change of the lighting systems and other externalities.

- Local insects, plants and mammals are progressively being replaced by external invasive species.

- Increase in road accidents in dark areas since deer cross streets to follow their natural needs in those few dark spaces that are left in the region.

- Due to the systems dynamics, disturbance of the food producing elements of the system through light pollution can reduce the provision of key ecosystems services.

\begin{tabular}{|c|c|l|}
\hline
H & 16.6 & Effective institutions: develop effective, accountable and transparent institutions at all levels
\hline
\end{tabular}

As with all sustainable development issues, light pollution is driven by people – either positively or negatively – and people organise themselves for action through institutions. Effective, accountable and transparent institutions at the international, national, regional and local level are essential to achieving sustainable development and have the greatest potential to impact upon light pollution. Institutions can serve to: (1) carry out relevant scientific, technical and social research to identify problems and possible solutions; (2) develop appropriate goals, strategies, policies, standards and regulatory frameworks; (3) provide financing and other required resources; (4) manage the implementation of action plans; (5) educate, mobilise and bring together stakeholders through collaborative frameworks for action; and (6) function as information / memory banks on key issues.

\textsuperscript{205} Stone, E.L. et al. (2015)
\textsuperscript{206} Plummer, K. et al. (2016)
\textsuperscript{207} NPR (2017)
Tackling Light Pollution for Sustainability – An Approach for the Vesancy-Versoix Corridor

Prioritizing for policy action

Following a similar, more simplified approach to Table 2: Impact of light pollution on selected SDG targets, and impact of selected SDG targets on light pollution, Table 3 supports decision-making in prioritizing for policy action relating to tackling light pollution based on the potential impact of these actions on sustainable development. It combines the original horizontal and vertical sums of the influences of each target with the above H/M/L ratings of light pollution’s impact on and by the target. For this, the H/M/L ratings are given the scores for impact of 3 (high), 2 (moderate) and 1 (low). The resulting scored impacts of light pollution on each target, and of each target on light pollution, are shown in Table 3:

Table 3: Cross-impacts of light pollution and 13 selected SDG targets

<table>
<thead>
<tr>
<th>A. Targets influencing other targets</th>
<th>B. Combined sum of influences</th>
<th>C. Light pollution on target</th>
<th>D. Target on light pollution</th>
<th>E. Light pollution through the target ((B\times C))</th>
<th>F. The target on light pollution ((B\times D))</th>
<th>G. Impact score combined ((E+F))</th>
<th>H. Ranking of light pollution actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food production / agriculture</td>
<td>23+33=56</td>
<td>3</td>
<td>-</td>
<td>168</td>
<td>-</td>
<td>168</td>
<td>3</td>
</tr>
<tr>
<td>Non-communicable diseases</td>
<td>4+21=25</td>
<td>3</td>
<td>-</td>
<td>75</td>
<td>-</td>
<td>75</td>
<td>11</td>
</tr>
<tr>
<td>Technical / vocational skills</td>
<td>30+24=54</td>
<td>-</td>
<td>3</td>
<td>-</td>
<td>162</td>
<td>162</td>
<td>4</td>
</tr>
<tr>
<td>Water-related ecosystems</td>
<td>9+20=29</td>
<td>3</td>
<td>-</td>
<td>87</td>
<td>-</td>
<td>87</td>
<td>10</td>
</tr>
<tr>
<td>Renewable energy</td>
<td>12+4=16</td>
<td>3</td>
<td>-</td>
<td>48</td>
<td>-</td>
<td>48</td>
<td>13</td>
</tr>
<tr>
<td>Energy efficiency</td>
<td>20+15=35</td>
<td>3</td>
<td>-</td>
<td>105</td>
<td>-</td>
<td>105</td>
<td>8</td>
</tr>
<tr>
<td>Infrastructure / clean technology</td>
<td>28+25=53</td>
<td>1</td>
<td>2</td>
<td>53</td>
<td>106</td>
<td>159</td>
<td>5</td>
</tr>
<tr>
<td>Affordable housing</td>
<td>13+17=30</td>
<td>1</td>
<td>3</td>
<td>30</td>
<td>90</td>
<td>120</td>
<td>7</td>
</tr>
<tr>
<td>Transport</td>
<td>21+21=42</td>
<td>2</td>
<td>3</td>
<td>84</td>
<td>126</td>
<td>210</td>
<td>1</td>
</tr>
<tr>
<td>Waste</td>
<td>29+18=47</td>
<td>2</td>
<td>-</td>
<td>94</td>
<td>-</td>
<td>94</td>
<td>9</td>
</tr>
<tr>
<td>Forests</td>
<td>12+20=32</td>
<td>2</td>
<td>-</td>
<td>64</td>
<td>-</td>
<td>64</td>
<td>12</td>
</tr>
<tr>
<td>Biodiversity</td>
<td>16+28=44</td>
<td>3</td>
<td>-</td>
<td>132</td>
<td>-</td>
<td>132</td>
<td>6</td>
</tr>
<tr>
<td>Effective institutions</td>
<td>51+17=68</td>
<td>-</td>
<td>3</td>
<td>-</td>
<td>204</td>
<td>204</td>
<td>2</td>
</tr>
</tbody>
</table>

By combining the above two scored impacts, one can arrive at a ranking for prioritising the 13 selected targets where actions relating to reducing light pollution would potentially have the greatest overall impact on sustainable development – in our case in the context of the Greater Geneva area.
Tackling Light Pollution for Sustainability – An Approach for the Vesancy-Versoix Corridor

The above table 3 shows that Transport (11.2) has the highest ranking of the light pollution actions because of the very high impact of light pollution reduction measures on transport and vice versa (i.e. the linear causal chains are bidirectional). The same is true for a lesser extend for the following SDG targets on Infrastructure/clean technology (9.4) with governments, industries and individuals being more dependent on technology; Affordable housing (11.1), which can be reinforcing when providing wellbeing or counteracting when sole financial calculations predominate environmental and social matters.

As biodiversity has been shown to be the highest risk planetary boundary, and, furthermore, because it is also known that light pollution has a direct and substantial impact on biodiversity, this SDG target 15 is considered in this paper to be the subject of highest priority. Additionally, the loss of biodiversity is irreversible. Once species are extinct, they will not reappear. Therefore, its above ranking has been moved in the table below from rank number 6 to number 1.

Table 4: Prioritization of SDG targets relating to light pollution

<table>
<thead>
<tr>
<th>Light pollution action</th>
<th>SDG targets</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Biodiversity</td>
</tr>
<tr>
<td>2</td>
<td>Transport</td>
</tr>
<tr>
<td>3</td>
<td>Effective institutions</td>
</tr>
<tr>
<td>4</td>
<td>Food production/agriculture</td>
</tr>
<tr>
<td>5</td>
<td>Technical/Vocational Education and Training (TVET)</td>
</tr>
<tr>
<td>6</td>
<td>Infrastructure/clean technology</td>
</tr>
<tr>
<td>7</td>
<td>Affordable housing</td>
</tr>
<tr>
<td>8</td>
<td>Energy efficiency</td>
</tr>
<tr>
<td>9</td>
<td>Waste</td>
</tr>
<tr>
<td>10</td>
<td>Water-related ecosystems</td>
</tr>
<tr>
<td>11</td>
<td>Non-communicable diseases</td>
</tr>
<tr>
<td>12</td>
<td>Forests</td>
</tr>
<tr>
<td>13</td>
<td>Renewable energy</td>
</tr>
</tbody>
</table>

Based on our analysis, the above table shows the priorities we attach to policy actions relating to reducing light pollution under sustainability considerations. This table will be used in the next section as the framework for recommendations made based on the review of the two cases selected for the Vesancy-Versoix corridor.

In addition to the 13 SDG targets drawn from the Swedish study, there are additional SDG targets outside of the 34 selected for the Swedish study that are also relevant for light pollution and for the Grand Geneva’s Vesancy-Versoix corridor. The additional relevant targets identified are related to the following SDGs: (1) No Poverty, (2) End Hunger, (3) Good health and well-being, (6) Clean Water and Sanitation, (7) Clean Energy, (9) Innovation and Infrastructure, (11) Sustainable Cities and Communities, (12) Responsible Consumption and Production, (13) Climate Action, (14) Life Below Water, (15) Life On Land, (16), Peace, Justice and Strong Institutions, and (17) Partnerships for the Goals. These other targets were not covered at this stage due to limited ressources at time of research. Future research using the above approach could be carried out on this matter.
Tackling Light Pollution for Sustainability – An Approach for the Vesancy-Versoix Corridor

CHAPTER 4 - CASE STUDY ANALYSIS FOR THE VESANCY-VERSOIX CORRIDOR

Overview

The purpose of this paper has been to apply the knowledge acquired regarding light pollution and sustainable development – specifically regarding the protection of biodiversity and promoting human wellbeing – within the Vesancy-Versoix biological corridor. In doing this, it was considered useful to take two representative cases: one a commune on the French side of the border, and another on the Swiss side. This side-by-side review would ideally allow for identifying similarities and differences that would inform and enrich the analysis of the problem and outlining some ways forward.

These two communities were selected because of they reflect the diverse though similar historical, geopolitical, demographic and environmental aspects of the corridor as a whole, specifically: (a) encompassing urban, suburban, agricultural and natural environments and habitat types (biomes); (b) having resident populations – often short-term – that depend a lot on daily travel to Geneva or Lausanne for employment; (c) not having, as yet, adopted specific measures on sustainability nor to reduce light pollution; (d) changes in land use and habitat fragmentation due to construction. Divonne les Bains was also considered an interesting location due to its high reliance on health-based tourism and wealthy secondary homes.

The Franco-Valdo-Genevois agglomeration project (Greater Geneva) was developed from cross-border approaches undertaken for several decades. The signing of its Charter in 2007 allowed the elaboration of a scheme based on three major complementary components: urbanization, mobility and the environment. This Charter insists that "...all the partner territories of the agglomeration are aware of these issues and make the preservation of the environment, sensitive agricultural and natural spaces a top priority of their planning...".

Substantial loss of natural areas and of biodiversity has taken place in the Grand Genève area208 over recent years, the result of accelerating urbanization. The loss of green areas and diminished contact with nature has had an inevitable impact on human health and wellbeing – a phenomenon well documented from experiences across the globe. In an attempt to protect and promote the development of natural areas for flora and fauna, eight cross-border biological corridors have been set up in the region in 2012209. Having signed Franco-Swiss contracts accordingly, these engage the regional communities to implement the following actions: (1) integrate biological corridors into urban planning, (2) make inventories of fauna and flora determining the space needed for these, (3) carry out works to improve or create suitable sites, (4) promote awareness and capacity building to the population. Such corridors encompass both human and natural habitats. One of these is the “Vesancy-Versoix biological corridor”, which refers to “dark corridors” to fight light pollution while protecting regional fauna and flora sensitive to same210. While there is expressed willingness to collaborate on both sides of the border, there is competition with other political priorities and lack of financial or human resources to deal with environmental issues, as shown from mid-term review data211. The corridor has a surface of ca. 177 km² and 31 beneficiary communes. Activities under the

---

208 Grand Genève has a surface of 2.000km² with nearly 1 Mio residents
209 Grand Genève (2014a)
210 Grand Genève (2016)
211 Presentation Bilan mi-parcours, Contrat Corridor Vesancy-Versoix, 23.11.2016. See: Communauté des Communes du Pays de Gex (2016a)
Tackling Light Pollution for Sustainability – An Approach for the Vesancy-Versoix Corridor

agreement run from 2014 to 2019. There are several activities implemented concerning light pollution awareness.

The two cases

The two cases selected were Divonne-les-Bains (Pays de Gex, Department of Ain) in France and Mies (Canton of Vaud) in Switzerland. The communes were selected because of their similarities and their differences: they have some similar geographical features, including forests, marshlands and waterways, and either have a lake or border a lake. They contain smaller biological corridors that interconnect but are also partly fragmented. Being in proximity to Geneva, they both have relatively large international populations, with a range of different cultures. Although Divonne has forested hills and Mies does not.

Following, is a side-by-side comparison of the two communes outlining their geography and land use, general information, demographics and governance, a description of their lighting systems and energy use, an overview assessment of their levels of light pollution, and a short perspective on community awareness and approaches to dealing with this problem.

Table 5: Data on the two communes

<table>
<thead>
<tr>
<th>Geography and land use</th>
<th>Divonne les Bains (Ain, France)</th>
<th>Mies (Vaud, Switzerland)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total land surface</td>
<td>3,384 ha</td>
<td>347 ha</td>
</tr>
</tbody>
</table>

Table 5: Data on the two communes

- Divonne les Bains (Ain, France): Estimated from the maps: around two thirds are forested lands (including a natural reserve), with around 15% agricultural lands and the balance – around 20% – constructed areas and sports grounds. Constructed area is expected to increase by 250 ha by 2027 and by another 150 ha by 2030.
- Mies (Vaud, Switzerland): Around 35% forest, 35% agric. & 29% constructed. Constructed area is expected to remain stable in future.
Tackling Light Pollution for Sustainability – An Approach for the Vesancy-Versoix Corridor

### Total constructed land (est. from the maps)

<table>
<thead>
<tr>
<th>Divonne</th>
<th>Mies</th>
</tr>
</thead>
<tbody>
<tr>
<td>680 ha</td>
<td>101 ha</td>
</tr>
</tbody>
</table>

### General information, demo-graphics and governance

Divonne lies next to the Swiss border. It is a residential town for many “frontaliers” who work in Switzerland but is also a health spa & tourism town for people who come from all around to enjoy its thermal baths, the Casino, the beach at its lake, the hippodrome, its countryside and forested hills. As can be seen on the map, about two-thirds of the surface area of Divonne is made up of forested and natural areas. The town has 4 primary schools and a secondary college, as well as many restaurants, shopping opportunities, sports facilities, several children’s playgrounds, many flowered gardens (3-flower rating) and fountains. Divonne also sports an elegant venue for theatrical and musical performances, the Esplanade du Lac. It is the tourism focal point for the Pays de Gex and has the highest hotel occupancy rate in Dept. of Ain, and thus makes a special effort to bring in visitors by being attractive and different from the other communes in the region. Divonne is governed by a team made up of the maire, 8 adjoints du maire, and 19 conseillers municipales. It forms part of the Communauté des Communes du Pays de Gex (CCPG) governed by a Conseil Communautaire with a president, 10 vice-presidents and 42 delegates representing the communes in the region.

Mies is a middle-sized municipality of the Canton Vaud, with about 10% the land size of Divonne. The village is made up of about one third each of forested, agricultural and urbanised lands. Although Mies is much further from the Jura forests than Divonne, apparently some large fauna (e.g. roes) appear in the village grounds from time to time. The two communes are separated by about 9.2 km, although Mies has some properties beyond its borders, one of which lies close to the border of Divonne. About 70% of the active population works outside of the village, mostly in Geneva. The main Cantonal lake road and the Swiss railway line to Lausanne cut through the village, creating distinct zones. Mies offers group sports facilities to its members, including soccer and tennis fields. A prestigious polo club is also based in the commune. The Creuson canal that passes through the village is a side stream of the Versoix river (which has its source as the Divonne river in Divonne les Bains). The municipality belongs to the District of Nyon. The village is governed by a Conseil Communal (executive, with 45 members) and a Municipalité (executive, with 5 members). Mies is directly at the border with Versoix, which is in the Canton of Geneva.

<table>
<thead>
<tr>
<th>2009</th>
<th>2017</th>
<th>% incr.</th>
<th>Comments</th>
<th>2009</th>
<th>2017</th>
<th>% incr.</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population</td>
<td>8,138</td>
<td>9,600</td>
<td>2.3% per year</td>
<td>Projected to 2027: 1.8% per year</td>
<td>1,764</td>
<td>2,042</td>
<td>2% per year</td>
</tr>
<tr>
<td>Density</td>
<td>2.40 persons/ha</td>
<td>2.83 persons/ha</td>
<td>18%</td>
<td>Over the 8 years</td>
<td>5.08 persons/ha</td>
<td>5.88 persons/ha</td>
<td>15.7%</td>
</tr>
</tbody>
</table>

### Description of lighting system

Divonne les Bains distinguishes itself from the start through its special luminescent blue and white lighting that greets visitors as they enter Divonne from Switzerland. This complements the new attractive street luminaires that run along the entrance Rue de Genève all the way to the Rond Point des Drapeaux. By all evidence, these are the best and least-polluting lighting that Divonne has to offer: the lamps shine down mostly on the road, are a warm yellow colour, and show almost no glare as one drives down the street. The lamps located on the side-street to enter the Val Vital spa also minimise light pollution (they are like the lights used in the commune of Sauverney –

Mies still has a large proportion of its street-lights made up of mercury vapour lamps, which are being phased out in most places, followed by metal halide and high-pressure sodium. Many of these are white lights, and thus more light-polluting. Private lamps also contribute to the problem: right in the middle of the village is a grocery store (épicerie) that has installed two blinding white lights on its shop sign that shine onto the street all night, without regulation. All public lights are centrally controlled, not by sectors. Any new luminaires purchased would be expected to have time controls; currently the only on-off controls are calendar season-based,

---

212 Service Cantonal de Recherche et d’Information Statistiques (2000)
more on this later below)\textsuperscript{213}, though they are not “insect-friendly” since insects can burn on the bulbs. Divonne has many other attractive street lamps, including many of traditional design and of a warm colour (especially in the downtown area and in the centre of its villages, e.g. Vesenex), but these all have relatively high degrees of glare. Some lights in the downtown area are dimmed late at night\textsuperscript{214}. The lamps around most of lake Divonne (except from those nearby the entrance to the beach) are very white lights and create substantial amount of glare (even across the lake), making it very unattractive to walk at night around the pedestrianised road that circumvallates the lake. Furthermore, there are extremely bright lights illuminating the underside of weeping willow trees in the lake’s port area. This lighting likely has a detrimental effect on the lake’s water ecosystem, possibly contributing (along with agricultural fertiliser runoff) to the excessive algal growth (night light is known to inhibit zooplankton from rising from deeper waters to graze on algae nearer the surface in waterways). The lights atop the nearby Esplanade du Lac are extremely bright, similar to flood lights. They shine on cherry trees that appear to show seasonal dislocation (flowers blossoming in mid-autumn\textsuperscript{215}). The lights around the lake and at the Esplanade are said to be turned off at night, but the author’s visits to the lake after 01h00 / 01h30 was unable to confirm this. The author observed several drivers not turning on their car lights at the Esplanade theatre and downtown because of the brightness of the streetlights. Otherwise, the lighting along the streets of Divonne is the usual combination of streetlight technologies: mostly metal halide and high-pressure sodium, followed more recently by LEDs. All of the LEDs downtown are under 3,000 kelvin. The LEDs installed on D15A are extremely bright and instil glare while driving a vehicle\textsuperscript{216}. Metal halide and LEDs – and to a lesser extent HPS lamps – have been used to replace the few remaining mercury vapour lamps and fluorescent lamps. The lights are centrally controlled. In the context of a new building project in the quartier de la Gare, the commune intends to set up “an intelligent lighting system (better orientation, reduced energy consumption) ...” and to apply these rules in its future urban development plans. Although the commune makes its own lighting system decisions, management of the system has been delegated through a Public-Private Partnership (PPP) to a company named CITEOS.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>although one street has movement-sensors to control lighting. The municipality had intended to change about 100 of its traditional-looking lamps into modern-looking LEDs (at a cost of CHF 250,000, including CHF 50,000 for cabling) to save around CHF 11,000 per year in energy costs, but after installing only 7 of these in the town centre the village’s population rejected further change in a referendum, for mostly aesthetic reasons. It appears that Federal subsidies could be used to help finance the eventual change to LEDs. The Cantonal authorities plan to change the lighting on the main cantonal road (Route Suisse), but Mies would have to pay for this change even though it would not be able to decide on which lamps to install (latter TBC). Planned new lighting includes installing floodlights for the football field, with the intention being to ensure that this light does not illuminate beyond the field. The village’s existing tennis court lights are key-activated and turn off at 22h00. No lighting is installed nearby the local forests (private properties nearby or on the forests were sensitized to turn off any lights shining on these natural areas). Responsibility for planning and financing of the village lighting systems rests with the municipality, whereas installation, management and maintenance has been tendered out to a private firm, Duvois-Groux. Recyclability will not figure as an evaluation criterion for future lighting purchases.</td>
<td>We do not know the exact type of lighting, nor the spectrum of these lights. Field trips could not clearly identify them. We observed the flowering of buds in early November 2017, when the trees had shaken off their leaves to prepare for winter. As there had been unusual warm weather and droughts during autumn, we assume that part of the budding can be correlated to climate change. However, due to the scientific research on artificial light on tree budding, we assume that the heavy lighting could contribute to this unnatural behaviour. Some drivers might need to put down the sunshade to avoid glare.</td>
</tr>
</tbody>
</table>

\textsuperscript{213} We do not know the exact type of lighting, nor the spectrum of these lights.
\textsuperscript{214} Field trips could not clearly identify them.
\textsuperscript{215} We observed the flowering of buds in early November 2017, when the trees had shaken off their leaves to prepare for winter. As there had been unusual warm weather and droughts during autumn, we assume that part of the budding can be correlated to climate change. However, due to the scientific research on artificial light on tree budding, we assume that the heavy lighting could contribute to this unnatural behaviour.
\textsuperscript{216} Some drivers might need to put down the sunshade to avoid glare.
## Tackling Light Pollution for Sustainability – An Approach for the Vesancy-Versoix Corridor

### Type of lamp / luminaire

<table>
<thead>
<tr>
<th>Type</th>
<th>2009 No.</th>
<th>2017 No.</th>
<th>% incr.</th>
<th>Location &amp; comments</th>
<th>2009 %</th>
<th>2017 %</th>
<th>% incr.</th>
<th>Location &amp; comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Mercury vapour</td>
<td>1,043</td>
<td>97</td>
<td>-90.7%</td>
<td>No longer accepted</td>
<td>49.7%</td>
<td>32.1%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. Metal halide</td>
<td>346</td>
<td>957</td>
<td>176.6%</td>
<td>Town centre</td>
<td>16.5%</td>
<td>33.8%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>c. Fluorescent</td>
<td>78</td>
<td>35</td>
<td>-55.1%</td>
<td></td>
<td>3.7%</td>
<td>4.5%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>d. LED 4,000 k</td>
<td>n.a.</td>
<td>7</td>
<td>23.6%</td>
<td></td>
<td></td>
<td>2.3%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>e. LED up to 3,000 k</td>
<td>135</td>
<td>351</td>
<td>160%</td>
<td>Town centre</td>
<td>6.4%</td>
<td>33.8%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>f. High pr. Sodium</td>
<td>495</td>
<td>747</td>
<td>50.9%</td>
<td>Outside of centre</td>
<td>23.6%</td>
<td>33.8%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>g. Eco (?)</td>
<td>n.a.</td>
<td>18</td>
<td>5.8%</td>
<td></td>
<td></td>
<td>2.3%</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>2,097</td>
<td>2,187</td>
<td>4.3%</td>
<td></td>
<td>100%</td>
<td>100%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Lighting facts

<table>
<thead>
<tr>
<th></th>
<th>2009</th>
<th>2017</th>
<th>% incr.</th>
<th>Comments</th>
<th>2009</th>
<th>2017</th>
<th>% incr.</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. luminaire per inhabitant</td>
<td>0.26</td>
<td>0.23</td>
<td>-12%</td>
<td>n.a.</td>
<td>0.15</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. luminaire per hectare (total)</td>
<td>0.62</td>
<td>0.65</td>
<td>4.8%</td>
<td>n.a.</td>
<td>0.89</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. luminaire per constructed ha (est.)</td>
<td>n.a.</td>
<td>3.22</td>
<td>-</td>
<td>n.a.</td>
<td>3.05</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percentage of luminaire that are white light (&gt;3,000k)</td>
<td>76.4%</td>
<td>65.8%</td>
<td>10.6%</td>
<td></td>
<td>78.6%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Costs of public lighting

<table>
<thead>
<tr>
<th></th>
<th>2016 (in euros)</th>
<th>2017 (in euros)</th>
<th>% incr.</th>
<th>Comments (figures in euros)</th>
<th>2009 (in CHF)</th>
<th>2014 (in CHF)</th>
<th>% incr.</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yearly investments</td>
<td>286,785</td>
<td>308,195</td>
<td>7.5%</td>
<td>2014: 314,273</td>
<td>n.a.</td>
<td>CHF 200,000</td>
<td>next 4 years</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2015: 252,210</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintenance &amp; license fees</td>
<td>182,000</td>
<td>190,000</td>
<td>4.4%</td>
<td>2014: 145,000</td>
<td>n.a.</td>
<td>30,800</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2015: 192,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electricity</td>
<td>147,785</td>
<td>124,371</td>
<td>n.a.</td>
<td>2014: 137,685</td>
<td>n.a.</td>
<td>25,400</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(year not completed)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

217 Ordered from the estimated most to least light polluting.
218 This type of lamp is unknown to the author, and its qualities are therefore unspecified.
219 This increase is possibly a consequence of the rebound effect resulting in more luminaires being installed because of lower energy costs due to local generation (from renewables).
220 Once again, this increase possibly means Divonne is investing in more luminaires as a rebound effect because of lower energy costs due to local generation (from renewables).
### Energy consumption for public lighting

Up to 86% of the energy used for public lighting is generated through local renewable sources exchanged through the grid (ERDF), notably the small hydro plant (aqualienne) in the town centre powered by the Divona river and solar panels installed on the roof of the hippodrome. Some lamps in the lake port area are autonomously powered by their own solar panels. The remaining 14% of required energy is purchased from the ERDF grid, through a “green energy” contract. The fact that energy consumption for public lighting is thus relatively low cost to the commune, poses a high risk that more luminaires than actually needed might be installed, the so-called “rebound” effect. Perhaps an indication of this is the 4.8% increase in the number of luminaires per hectare between 2009 and 2017 (above).

<table>
<thead>
<tr>
<th>Sources of energy</th>
<th>2017</th>
<th>Comments</th>
<th>2017</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fossil fuels</td>
<td>-</td>
<td></td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Nuclear</td>
<td>-</td>
<td></td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Renewables:</td>
<td>100%</td>
<td>Including local sources plus ERDF green contract</td>
<td>Romande énergie offers 4 contract options: (1) Undefined, (2) 60% hydro / 40% nuclear, (3) 100% hydro, (4) 20% solar / 80% hydro</td>
<td>It was not possible to find out which type of contract the commune has chosen.</td>
</tr>
<tr>
<td>• Solar</td>
<td>86% of total consumption</td>
<td>Locally generated</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Hydroelectric</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Light Pollution

The highest priority under the PPP with CITEOS is given to saving on costs, especially energy costs. Only relatively recently is attention being given to light pollution. Thus, interest has been expressed in reducing some luminaires and in installing intelligent lighting systems adapting to needs. There is also the intention to encourage the private and residential sectors to reduce their share of the town’s light pollution. The municipal authority’s position is not clear regarding the adoption of a Charter (e.g. the ANPCEN Charter) committing to reducing light pollution. This could be important, as the current levels of light pollution in Divonne (as in other large communes in the region) have been measured as relatively high – deep orange to red – an artificial brightness value of 890-1,780 μcd/m² in the colour scale (ranging from <1.74 to >7,130 μcd/m²) developed for the New world atlas of artificial night sky brightness.

As shown by the New world atlas of artificial night sky brightness, light pollution in Mies is high but not as high as in central Divonne. The Google Earth-based image below shows Mies at a solid orange – from 445-890 μcd/m² in the atlas colour scale (ranging from <1.74 to >7,130 μcd/m²) which reflects the level of difficulty in observing the night sky due to light pollution. Through its Plan General d’Affectation, the village intends to formally specify new rules for the commune regarding lighting. The municipality is aware of the new lighting guidelines of the Federal Office for the Environment (BAFU) to reduce light pollution and intends to take these into account in its future lighting projects. It would prefer to reduce overall lighting density in the village, with more dark areas. For future projects, the commune intends to implement movement detectors and downward directed light. Lighting guidelines may also apply eventually to authorising private building permits.

---

221 To view the atlas, open on Google Maps / Google Earth: [http://pmd.gfz-potsdam.de/contact/NewWorldAtlas_ArtificialSkyBrightness.kmz](http://pmd.gfz-potsdam.de/contact/NewWorldAtlas_ArtificialSkyBrightness.kmz). The author received licence from Dr Falchi to peruse the data. Authors of the article in Science Advances Vol 2 No 6 of The new world atlas of artificial night sky brightness are Fabio Falchi, Pierantonio Cinzano, Dan Duriscoe, Christopher C. M. Kyba, Christopher D. Elvidge, Kimberly Baugh, Boris A. Portnov, Nataliya A. Rybnikova and Riccardo Furgoni (2016). See Falchi, F. et al. (2016).
Table 6: Colour levels used in the New World Atlas maps and zoom in on study perimeter

<table>
<thead>
<tr>
<th>Ratio to natural brightness</th>
<th>Artificial brightness (µcd/m²)</th>
<th>Approximate total brightness (µcd/m²)</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;0.01</td>
<td>&lt;1.74</td>
<td>&lt;0.176</td>
<td>Black</td>
</tr>
<tr>
<td>0.02-0.02</td>
<td>1.24-3.48</td>
<td>0.176-0.377</td>
<td>Dark gray</td>
</tr>
<tr>
<td>0.04-0.08</td>
<td>3.48-6.96</td>
<td>0.177-0.381</td>
<td>Gray</td>
</tr>
<tr>
<td>0.08-0.15</td>
<td>6.96-13.9</td>
<td>0.181-0.386</td>
<td>Dark blue</td>
</tr>
<tr>
<td>0.16-0.32</td>
<td>13.9-27.8</td>
<td>0.185-0.392</td>
<td>Blue</td>
</tr>
<tr>
<td>0.32-0.64</td>
<td>27.8-55.7</td>
<td>0.202-0.403</td>
<td>Light blue</td>
</tr>
<tr>
<td>0.64-1.28</td>
<td>55.7-111</td>
<td>0.230-0.410</td>
<td>Dark green</td>
</tr>
<tr>
<td>1.28-2.55</td>
<td>111-223</td>
<td>0.285-0.457</td>
<td>Green</td>
</tr>
<tr>
<td>2.36-5.12</td>
<td>223-445</td>
<td>0.397-0.519</td>
<td>Yellow</td>
</tr>
<tr>
<td>5.12-10.2</td>
<td>445-896</td>
<td>0.619-1.065</td>
<td>Orange</td>
</tr>
<tr>
<td>10.2-20.3</td>
<td>890-1790</td>
<td>1.07-1.36</td>
<td>Red</td>
</tr>
<tr>
<td>26.5-41</td>
<td>1780-3560</td>
<td>1.95-3.74</td>
<td>Magenta</td>
</tr>
<tr>
<td>&gt;41</td>
<td>3560-7130</td>
<td>&gt;3.70</td>
<td>Pink</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt;7130</td>
<td>White</td>
</tr>
</tbody>
</table>

Source: Falchi, F. et al. (2016)

“…People living near Paris would have to travel 900 km to Corsica, Central Scotland or Cuenca province, Spain, to find larger territories where the zenith is essentially unaffected by light pollution (artificial sky brightness < 8% of the natural background); even in these places, significant sky glow would be present near the horizon. The pristine sky (artificial sky brightness < 1% of the natural background) nearest to Neuchâtel, Switzerland, is more than 1,360 km away, in northwestern Scotland, Algeria, or Ukraine…” 222. Neuchâtel is ca. 100 km away from Divonne les Bains and Mies.

222 Falchi, F. et al. (2016)
To date, there is no substantive review of the state of biodiversity in Divonne les Bains, nor in the Pays de Gex. Thus, it is not possible to begin to substantively assess the impact of light pollution (or any other human induced changes) on its fauna and flora. However, one may reasonably assume that the effects will be similar to those exhaustively reviewed in the scientific literature, as described earlier. As Divonne encompasses part of a departmental natural reserve, we assume that it possesses a relatively high degree of biodiversity for the region, and needs to protect it from harmful effects, including from light pollution. It also comprises water ecosystems, including sensitive, protected marshlands. The latter appear to be relatively well protected by forest from light pollution. The area around Divonne-Mont Mourex-Vesancy towards Gex features a natural biological corridor that is officially protected at European level. It is important to note here that Divonne is located on bird migration paths, and that local light pollution – particularly at the Divonne lake, which serves as a transit point for water fowl – may have an impact on these birds. Reference has already been made above to the possible effect of light onto algal growth in the lake. Data is currently unavailable regarding the impact of light pollution on the health of the commune’s residents, although there have apparently not as yet been complaints to the Mairie concerning problems of public lighting trespass. Nevertheless, Divonne’s spa promotes itself for its cures for mental anxiety and psychosomatic illnesses. The entrance lighting to the spa is suitably dim and focused. However, other lighting in the town may have a detrimental effect on the sleep and tranquillity of patients, detracting from the usefulness of the spa’s cures. Such cures are an important part of Divonne’s attraction for visitors and tourists, and reducing light pollution across the town can only help to encourage more visitors to come.

Ad hoc studies on biodiversity at the lakeside of Lac Léman have shown increases in the bird population, but losses in the populations of amphibians and insects. Light pollution may have played a role in this regard. Mies is a location that encompasses not only waterways but also forested areas where large fauna have been seen. Further assessments of the impact of light pollution on biodiversity in the natural areas of Mies will need to be undertaken to obtain a clearer picture. Likewise, data is currently unavailable regarding the impact of light pollution on the health of the commune’s residents. However, there are already many residents’ complaints being received at the municipality about street light going into homes. This could be an indicator of light pollution affecting people’s sleep, with possible longer-term health impacts.

A special permit was obtained to build a new fire brigade serving Gex, Vesancy and Divonne towards the Gex area of this corridor.
Tackling Light Pollution for Sustainability – An Approach for the Vesancy-Versoix Corridor

### Biodiversity Damage Potential

Assuming that the Vesancy-Versoix corridor profile is broadly similar to the overall profile for Switzerland (since this is a biome of temperate broadleaf and mixed forests), one can estimate that the Biodiversity Damage Potential for the corridor at 0.39. To reach the Aichi targets by the year 2020 under the Convention of Biodiversity, this would have to be reduced by 0.16, i.e. by almost 60%\(^\text{225}\). Reducing light pollution can be one of the means to achieving this.

### Community awareness & some approaches to reducing light pollution

Some of the commune’s residents are consulted from time to time on matters concerning Divonne’s urban development plans\(^\text{226}\). Consultations have not yet taken place regarding the commune’s lighting systems, although the ongoing project was part of the election platform of the current municipal government. There is support for raising awareness regarding light pollution, particularly in schools for children and youth. There is also some expressed interest in trans-border collaboration in reducing light pollution, taking account of the particularities of France and of Switzerland. The town’s maire and his adjoint have both expressed an understanding of the problem of light pollution and of the desire and need to do something about this. Short personal interviews carried out under the Capstone project with residents of Divonne at various locations have shown that there is interest – sometimes even strong interest – in the topic and a willingness to do something about it. However, much awareness-raising remains to be done on understanding the nature and types of light pollution, its effects on people and on biodiversity, and the straightforward ways in which it can be tackled. Beyond this, mobilisation of residents to become involved in pressing for action and in decision-making will be most important for progress to be made.

The municipality believes that awareness of the need for prudent lighting is increasing, along with awareness of other environmental issues such as waste and climate change. There are thoughts on how to balance the wish for less lighting with the need for lighting and to being in line with the cantonal street lighting regulations on conformity. There appears to be little on this topic for children in the local school. The population generally does not appear to want so much light (as per the complaints about light trespass into homes, referred to above). This was also experienced by the author in an \textit{ad hoc} street-side interview with local residents after 01:00 hrs in the centre of the village. The public seems aware of the health consequences of light pollution, and also its impact on biodiversity, but appears less concerned about the latter. The Conseil Communale and its Environmental commission demonstrate much concern for issues of sustainable development. Since the issue of light pollution is perceived as a new topic, moving forward in little steps might be one of the approaches.

### CHAPTER 5 – DPSIR ANALYSIS

The above chart describes the current state of the two communes, specifically focusing on lighting systems and light pollution and its effects on biodiversity and on human health – the extent of which is not yet known and will need to be the subject of further study. At this point, it is useful to apply the DPSIR assessment framework approach\(^\text{227}\) (see Annex 5) to better understanding the \textbf{Drivers} and \textbf{Pressures} that have led to this situation, the \textbf{State}, and to attempt to further assess the \textbf{Impacts} that light pollution is likely to be causing. From this, a \textbf{Response} to the problem will be outlined in terms of the conclusions and recommendations of this paper.

\[^{224}\text{Baan, L. de et al. (2013)}\]
\[^{226}\text{Communauté des Communes du Pays de Gex (2016b) and (2016c)\textit{}}\]
\[^{227}\text{Kristensen, P. (2004)\textit{}}\]
Drivers and pressures

Socio-economic drivers for light pollution in Divonne and Mies include:

- **Demographic growth.**
  
  More people generally equals more light, whether this comes from new streets or new homes or new services (shops, restaurants, etc.) to meet their needs. Population growth has been somewhat higher over the last 8 years for Divonne (around 2.3% per year) than for Mies (around 2% per year). However, its demographic growth is expected to slow down to 1.8% per year onwards to 2030, which may be helpful in at least controlling any increases in light pollution or making reductions easier.

- **Changes in land use and land fragmentation.**
  
  Growing urbanisation is encroaching upon agricultural and natural areas, particularly in Divonne (where the constructed area is expected to increase by 250 ha by 2027 and by another 150 ha by 2030). This increase in building infrastructure – residential, commercial/industrial and administrative – generally leads to the installation of more street lights and also more light being emitted from the buildings themselves (e.g. shops, homes, etc. as described above). Lighting on certain routes may be made unnecessarily brighter to account for the belief that this will help to avoid accidents from increased traffic (see below)\(^{228}\). In this context, Mies may find its light pollution increased by the Cantonal decision (in which the village is not involved) to change its existing high-pressure sodium lamps on the Route Suisse, especially if the result is the installation of LEDs above 3,000 k (which are detrimental to biodiversity while today displaying the highest energy-efficiency).

- **Increase in the numbers of vehicles circulating, and longer commuting to work.**
  
  This results in what is called “mobile light pollution”, created by the lights of vehicles. With greater population density comes more traffic and more congestion. As more people decide to live further away from Geneva or other Swiss towns (where housing is often expensive or scarce and where most employment in the region is to be found), their commuting routes to work becomes longer. In the case of Divonne, this traffic is coming from town but also from Gex and other locations in the Pays de Gex transiting through the town. Increasing traffic on the Route Suisse is likely to be causing more mobile light pollution to Mies. The Pays de Gex intends, through its new “Sustainable Development Project” (PADD) to encourage the use of public transport, which should be helpful for many other reasons in addition to reducing light pollution. Over the longer term, the introduction of driverless vehicle-based mobility services linked to the region’s public transport services should result in a marked reduction of privately owned and driven vehicles on the road, at the same time also reducing mobile light pollution.

- **Human activity at night:**
  
  As people try to extend the light of day into the night for leisure and economic purposes, external light pollution is created, sometimes even enforced. This includes desire to attract tourists by making the town look brightly lit. This paradigm ignores the fact that darkness, pristine sky and intelligent moderate time-adapted lighting can themselves serve to attract tourism.

---

\(^{228}\) Judicious use of lighting can help to avoid accidents at some locations. However, light glare can actually be the cause of accidents.
Tackling Light Pollution for Sustainability – An Approach for the Vesancy-Versoix Corridor

The communes’ public-sector policies and investments also play a key role, for instance:

• **Increases in public infrastructure investments.**

These often lead to more roads and more or stronger street lights. The municipal authorities in both Divonne and Mies seem to be conscious of this risk, however, and appear ready to assess the needs for any new lighting systems very carefully. On the other hand, if investment funds are restricted or are targeted at other projects – which currently appears to be the case at least for Divonne (where local taxes are going up to fill a gap in the commune’s budget) – then investing in improved lighting systems to reduce light pollution may be put off for some time, perhaps a long time. This will happen as long as attention to the new pollution-reducing lighting systems would not receive the highest priority from the municipal authorities; and this may sometimes not happen unless citizens / electors remind them one way or another that this is also everybody’s priority. This requires citizens’ awareness and commitment to change. More on this later below.

• **Tackling light pollution vs. energy savings.**

The second issue here is when – also because of budgetary constraints – priority when implementing change is given to savings in energy expenses for public lighting over reducing light pollution. The result may be to go for lighting options resulting in the greatest economies – for instance white-blue light colour LEDs (4,000 k or above) – without considering that these may produce harmful increases in light pollution; causing harms of which one might not be aware. After having installed 7 such LED lamps and prior of replacing 100 more, the project was halted by a local referendum. Indeed, the village folks voted against the change for aesthetic reasons\(^\text{229}\) (traditional lamps were to be changed into modern “cobra-head” style lamps), rather than as a vote against light pollution: the lights to be replaced, and which have been kept standing, were mostly a combination of mercury vapour and metal halide lamps, both of which employ very white light and thus highly light polluting. Mercury vapour lights are also very environmentally polluting and dangerous due to the mercury they use for illumination, so the faster they are changed, the better (despite the fact that the European Union phases out mercury light bulbs by 2018 and that the Minimata Convention calls to phase out of mercury products, amongst others.

• **The legal frameworks governing public investments and lighting systems.**

These may encourage or discourage tackling light pollution and may sometimes be contradictory. For instance, in Switzerland roads that are built require by law a minimum amount of lighting. Such roads may not be dark. Yet, Switzerland is simultaneously working to strengthen its sustainability policies and practices, including federal guidelines on light pollution, which encourage lighting reductions. These systems apply of course to Mies, but are not mandatory. Another example are public procurement laws and regulations, which may require the purchaser (e.g. of lighting systems) to go for the supplier offering the lowest price or the lowest life-cycle cost, irrespective of how much light pollution is created. To offset this risk, the well-informed buyer must clearly state the measures to be built into the purchase specifications to minimise any light pollution.

---

\(^{229}\) Ebinger, R. (2017)
Psychological factors. There are numerous psychological factors influencing the acceptance or rejection of abundant light at night.

- In favour of abundant artificial light at night:

There are psychological reasons why people believe that artificial light at night is not only important, but essential. A main cause is the ancestral fear of the dark. The dark is equated with danger, and even with evil. Light is equated with liberation from this fear. In today’s world the main fears are of crime in all its forms, and of accidents – including vehicular accidents. The average resident of Divonne or Mies may not today fear attacks by unseen wild animals from the forest, but other humans may be seen as risks if their appearance and actions remain hidden in the shadows. The Association française de l’éclairage (AFE) claims that surveys have shown that 90% of people in France consider lighting essential to their security, and that 87% believe lighting to be important to road safety. These figures, if correct, may or may not accurately reflect attitudes in Divonne and Mies. In fact, nearly 100% of real-life ad-hoc night-time interviewees thought that there was too much light and a lot of glare. Only one male youth “did not care”. Little consideration in these claims is given to the fact that studies concerning public lighting as a deterrent to crime and to accidents are as yet inconclusive and even contradictory. The fact is that different types of crimes predominate at different times of the day and night, and that often outdoor lighting has little to do with what happens. Nevertheless, many people may just feel more comfortable being able to see who else is walking along the street and allow them more easily to engage in social interaction with neighbours and others outside at night. This has biological reasons as the human eye has difficulty in distinguishing color at night and in quickly adjusting vision when coming from an illuminated place to a dark place. Furthermore, illuminating public spaces as during daylight might facilitate CCTV observations to prevent crimes and to inquire after crimes respectively. Some consider darkness to be gender-discriminating, as women would be less likely than men to venture out on a dark night. The author’s general observation from walking about in Divonne and Mies at night is that – while some central areas of Divonne remain active late into the night – there are only few people out and about in the vast majority of the streets despite the bright lighting. Studies have shown that the later it is, the fewer women and older persons there are, and the more younger men appear to predominate, although there are also occasional couples walking about, and joggers. Additional psychological reasonings favouring artificial light at night include the perceptions that this represents modernity and advancement. Some decade ago, for example, builders refused to include smart energy-efficient lighting in newly constructed developments – despite advice from governmental officials - as they wanted to bring the feeling of living like in a city to a rural area and thus following the stigma of rural areas being more disadvantaged than cities.

- Against artificial light at night perceived as “excessive”:

Those who are against artificial light at night – or at least in favour of reducing and controlling it – are generally more appreciative of the beauty of the night sky, which they wish to recover, and keener to protect biodiversity from the harms of light pollution. They may also value the dark and gazing at the night sky.
stars as a source of peace and calm, even as a spiritually enriching act. People objecting to light pollution may furthermore be aware of the harm that it can cause to human sleep patterns, hormonal balance and mental and physical illness, and wish to protect themselves from this. They are also likely to question the belief that having bright lights on at all times is the best way to protect against crime and road accidents and that, on the contrary, if can actually foster such risks. A final psychological argument against light pollution will reflect the (high level of) discomfort felt about it being the cause of such a useless waste of energy, of money, of resources while contributing to loss of biodiversity, deterioration of health and increase of GHG.

To the extent that one or another of these psychological positions prevails over the other, and depending also on how strongly it is felt, this will strongly influence the rise or fall of light pollution given that ultimately it is people who will decide what is done about it. In the course of informal interviews on the streets of Divonne and Mies, there appeared to be a general appreciation of the dangers of light pollution, and annoyance over strong and disruptive lights (for instance, around the lake of Divonne). However, these positions seemed to be held without the conviction that would drive people to action. There would seem to be a need to reach a critical mass of people (11 % to 14 %) for change to come about. This is the key challenge in terms of sustainability resulting from this project and will be addressed below.

**Technological factors:**

- Lighting technology has been evolving in recent years towards the growing and even massive adoption of LED lighting. This type of lighting has several advantages, which encourage its acceptance. They are low energy consuming, and therefore cheap to use (using 40%-80% less energy than standard high pressure sodium lamps); are very long lasting (up to 100,000 hours) and requiring little maintenance; turn on instantly and can be easily dimmed, enhancing flexibility; reflect the true colours of objects; can be more easily directed to illuminate specified locations; are less affected by cold weather; and can be purchased now at reasonable cost. All of these features – particularly the low energy consumption costs – have caused rapid adoption in the region. Divonne has already installed 351 such lamps, a 150% increase over 2009. Mies would have installed 100 more than its current 7 LED lamps if the project had not been stalled by referendum. However, the production and recycling of LEDs is not necessarily environmental friendly (as it contains toxics and metal). LEDs also raise several risks in terms of light pollution. The first is that of a rebound effect, whereby they are cheap to operate then more of them can be bought and installed without the need for budgetary increases. If this leads to more illumination, it increases light pollution. The second risk is that – again because of their low energy consumption – lamps with increased luminance can be installed, again fostering light pollution. The other, critical, risk is that the cheapest LEDs to buy are those with white-blue lights (4,000 k and above). White light used at night is known to have the most detrimental effects on wildlife and plants, and also on humans. Furthermore, white light is reflected more readily than other spectrum lights, causing it to spread more extensively in the atmosphere. Skyglow, for example, is worse when there are more particles in the air, when it is more humid or snow acts as a reflector – conditions the Geneva basin encounters. This causes aggravated light pollution. Fortunately, more recently “warmer” LED light colours are becoming more readily available, allowing to overcome this problem. This, in combination with the flexibility of LED lights to be directed more precisely, dimmed, and turned on and off instantly allow this lighting technology to become a useful tool in efforts to reduce light pollution. It is expected that both Divonne and Mies will make good use of these features in planning their future lighting systems.
Tackling Light Pollution for Sustainability – An Approach for the Vesancy-Versoix Corridor

Current state of light pollution and trends

The Falchi et al. New World Atlas of Artificial Night Sky Brightness maps (which represent the level of difficulty in observing the night sky at different locations), and the comparative tables shown previously for Divonne and Mies, have illustrated the extent of their light pollution problems. Divonne is shaded reddish in the atlas and thus has a somewhat higher level of light pollution in its central area than Mies, but this drops to yellow when reaching its forested areas on the Jura mountains. On the other hand, Mies is uniformly orange. Its level of light pollution is thus lower, but more evenly spread around. Curiously, there appears on the atlas to be a greater light pollution effect on the Lake Léman waters in front of Mies than in Mies itself, perhaps generated by vehicles on the Route Suisse that runs along its coastline.

Satellite and visual observations show that there is a high degree of light pollution / artificial light at night in the region, as represented by the two sample communities of Divonne les Bains and Mies. The satellite data specify a level of pollution affecting the populations at these two locations that ranges from (a) the inability to view the Milky Way (represented in the orange colour code as per the legend in Falchi’s et al. World Atlas), up to (b) cone receptor stimulation in the eye (see the legend’s red colour code). As cone receptors are normally meant to be used only during the day, this means that true night conditions are non-existent as people must live (without using their natural rod receptor-based night view) under an artificial twilight.

Light pollution is generally influenced by the number and density of luminaires, the intensity of their light, the direction of the light and the amount of light “leakage” due to lack of shielding of the lamps, and the colour of the light (the whiter, the more light pollution). Not all of this information was available for this paper, so the full picture is not clear. However, the information that was available would seem to indicate that central Divonne’s higher levels of light pollution may be caused primarily by a higher density of luminaires in the town’s constructed zone (3.22 luminaires per hectare against 3.05 for the constructed zone in Mies). While Mies actually has a higher share of white-light luminaires than Divonne does (78.6% against 65.8%), Divonne’s may be brighter and / or leak more light into the environment and / or be more concentrated in the central areas of the town. From the local nocturnal orthophotos, a brilliant splotch of light outshining by far anything else in the neighbourhood and roundabout(s) areas are visible (see Annex 6). Other than street lights, light pollution in Divonne will also likely come from several upwards-directed illuminations of buildings (the City hall, churches, onto trees, etc.) and from commercial enterprises (many of which do not comply with French law to turn off their store lights by 01h00). Light pollution also comes from homes. There are several – and growing – numbers of very large homes (including one on the fringes of Divonne’s forested Jura hills and along the D15A) that display large and over the years increasing amounts of light indiscriminately and are very visible over long distances (kilometres). There appears to be no incentives and sensitization measures yet to control such light pollution. Mies is actively advising in terms of light pollution to selected targets, and those mostly follow the suggestions.

In Mies, light pollution is likely to be higher than it might otherwise be due to its reliance on white light luminaires (mostly mercury vapour and metal halide). Its new 7 LED white lights add substantially to this problem. These are located in the village’s central crossing and can be seen from the sky – through night sky aerial photographs obtained for this paper from the Système d’information du territoire à Genève (SITG). From the perspective of sustainable development and its environmental, economic and social

236 Falchi, F. et al. (2016)
dimensions, it may turn out to be fortunate that the village referendum postponed the decision on the new luminaires to be purchased, thus allowing time for a better decision to be made.

Generally, light is kept away from natural areas in both Divonne (except for national border crossings) and Mies. The trends described earlier regarding drivers and pressures – e.g. demographic and urban growth, traffic, infrastructure investments and budgetary constraints, the push for energy savings, changes national and local legal frameworks, etc.) can only mean that light pollution will increase over coming years in both Divonne and Mies unless awareness and willingness exist to control it.

Impacts of light pollution

The impacts of light pollution are becoming better known, but much research remains to be done on this matter. A more comprehensive review of the key impacts on human health and wellbeing, on biodiversity, and on energy consumption and GHG emissions has been provided earlier in this paper, and will therefore not be repeated here except for the summary given below. The fact that Divonne and Mies both comprise a similar variety of human, geographic and biosphere features (including forests, water-based ecosystems, migrating birds, large and small fauna, agricultural lands and urbanised areas) means that they will share similar risks regarding the effects of light pollution. Their proximity to Geneva means that they will also both continue to live under the umbrella of its sky glow (see above pink area of the photo above in the table representing Geneva) and its effects until the Canton and the City of Geneva also tackle its big light pollution problem.

Following is a summary listing of the main socio-economic and environmental impacts that may be expected if light pollution continues to afflict the two communes:

**Human condition, socio-cultural effects**

- Physical, mental, spiritual health and quality of life negatively affected by light pollution due to:
  - Sleep deprivation and hormonal changes resulting in depression, mental illness, cardiovascular disease, cancer, obesity, etc.
  - Inability to access the proven health/spiritual benefits of enjoying the beauty of the night sky and a deeper contact with nature/wildlife
- Limited opportunities for night-time, nature-related recreational activities (e.g. astronomy, night-walks, animal/birdwatching, nature hikes, etc.), with loss of recreational value for locals and of enhanced inbound tourism prospects
- Road stress/accidents caused by blinding light glare from other vehicles
- Human injuries/deaths from accidents at animal road crossings due to animals being blinded by light glare
- Reduced security due to thieves and other criminals taking advantage of the light exposure of potential victims and/or of light glare blinding their victims

**Agricultural areas**

- Reduced productivity of farmed crops and animals (incl. bees and moths) due to disruptions of their natural day/night cycles affecting their hormones, sleep patterns, etc. and photosynthesis and growth reactions of plants

---

237 The State of Geneva is inquiring this matter, and the Canton’s Department for the Environment, Transport and Agriculture (DETA) is proactively involved in addressing this issue together with partners. See République et Canton de Genüve, DETA (2015a,b; 2017)
Natural areas and biodiversity

- Negative effects on the growth and health of wild plants, animals and other life forms due to disruptions of their natural day/night cycles
- Substantial light-causing disruptions in the movements of wild animal for purposes of feeding, rest and reproduction, significantly affecting functional species- and genetic biodiversity
- Animal injuries and deaths from accidents at dark animal road crossings due to speeding vehicles with bright lights blinding the wildlife
- Decrease in resilience and loss of ecosystems and ecosystem services, and increases in non-indigenous/invasive species

Energy and GHG emissions

- Energy will continue to be wasted, whether or not it is generated from fossil fuels. To the extent that it is, then this waste will generate more CO2 and contribute to the serious global problem of climate change. If it generated from nuclear power, it will contribute to the generation of nuclear waste and to the as yet unsolved problem of how to dispose safely of this waste into the distant future.
- One way or another, this wasted energy will also mean wasted money, at a time when the communes of Divonne and Mies both face constraints on their budgetary resources. This means that these resources cannot be used for other more fruitful purposes, creating an opportunity cost.

Under the DPSIR Framework, the Responses are outlined in Chapter 6 (Conclusions and Recommendations).

CHAPTER 6 - CONCLUSIONS AND RECOMMENDATIONS

Conclusions

From the above, it is possible to conclude that light pollution is a key issue for the cross-border Vesancy-Versoix biological corridor of the Grand Genève agglomeration. The main source of outdoor light pollution is the public lighting of streets, parks, public buildings and monuments, sports venues and other public spaces. However, other important contributors to light pollution are road traffic, private homes (garden lighting), residential and office buildings and their parking spaces, luminous outdoor advertisements and commercial centres and their parking areas.

Light pollution has significant impacts on humans and on nature, even though these impacts are difficult to measure. It is thus important to take action through a longer-term vision involving comprehensive change at the social, institutional, cultural, economic and technological levels. It is also important to adopt concrete measures that can have an impact in the short term on reducing light pollution in order to enhance sustainability. These short-term actions can be linked to specific SDGs and targets (see Table 6).

Recommendations need to specify what type of lighting is appropriate, when it is appropriate and where it is appropriate. To be as sustainable as possible, the type of lighting needs to be no brighter than needed (i.e. as dim as possible at any point in time) and of a colour in the spectrum that does the least damage to living beings, usually in the yellow range. When it is appropriate means that sustainable lighting also must be time-based, i.e. turned on only when required for a specific purpose and otherwise turned off. Finally, where it is appropriate means that it should be directed specifically at those locations where it is required (e.g. shielded lights on roads), and not allowed anywhere else outside of those.
Tackling Light Pollution for Sustainability – An Approach for the Vesancy-Versoix Corridor

locations. This also means that no light should exist unless it is performing a clearly specified function. If alternative means exist to perform a given function (e.g. an anti-theft alarm system), they should generally be preferred. The function also needs to be sufficiently important to justify illumination. If the benefits of the function are less than the impact costs of the light pollution that is generated, then illumination is not justifiable.

There are several constraints and barriers to be tackled in order to achieve the proposed vision and contribute to attainment of the SDGs. These are described below, along with a strategy aimed at overcoming these barriers. The implementation of the strategy will require further research to identify and assess the barriers that are specific to achieving each individual Goal or target.

Recommendations

Responses

For this paper, we will apply the ABCD Planning Method of the Framework for Strategic Sustainable Development (FSSD). The method consists of defining a vision and awareness (A), mapping the baseline of the current reality (B), creating solutions (C), and devising a plan of action (D). If these impacts are to be avoided, or at least mitigated, responses needed are aimed at reducing light pollution in both communes. For this, it is necessary to articulate a common vision, i.e. where the region would like to be in terms of tackling light pollution by, for instance, 2030. The vision would normally be developed collaboratively by all concerned stakeholders, amongst others: the local municipal authorities, environmental protection organizations, health and social services, relevant scientific research bodies, public lighting services, energy providers, urban development agencies, road transit authorities, police and other security services, and, of course, community residents and their representatives. Given that this has not yet been possible, this paper attempts to reflect what the author believes might eventually result from such a consultative process, providing suggestions as to what the vision for the region might contain.

(A) Vision – desired outcomes

The following scenario for 2030 regarding sustainable lighting systems for the Vesancy-Versoix corridor (and beyond) is ambitious, but considered feasible. It is based on adherence to the four principles of sustainability: (i) not to systematically increase concentrations of substances extracted from the Earth’s crust; (ii) not to systematically increase concentrations of substances produced by society; (iii) not to systematically increase degradation by physical means; and (iv) not to allow conditions that systematically undermine the capacity of humans to meet their needs. Furthermore, the scenario described below addresses a range of institutional and legal, economic and financial, technological and socio-cultural issues, and seeks to overcome trans-border divides.

1. An Association of Communes of the Grande Genève for Sustainable Lighting will be in operation, bringing together specialists and representatives from the different communes to: (a) share expertise and experiences and provide guidance to communes on the continuous improvement and sustainability of their public lighting systems; (b) advise and support communes and other bodies (e.g. CCPG) in the region in dealing with suppliers of lighting systems so as to ensure the adoption of sustainable, light pollution-free lighting systems, and to coordinate or consolidate their acquisitions so as to benefit from bulk purchases and economies of scale; (c) organise and implement awareness and information campaigns and discussion forums for local residents, schools and businesses on sustainable lighting at the home, in the business, and in the public space; (d) collect, review and act upon any problems and issues concerning the sustainability of lighting
systems in the region, including their impacts on human health and wellbeing, on the biosphere and on energy efficiency and the adoption of renewable energies; (e) advise the communes on guidelines and harmonised regulatory measures that they can adopt to ensure the sustainability of – and to eliminate any light pollution from – lighting systems in public, commercial, industrial and private spaces; and (f) serve as a link to other bodies with similar aims in other nearby regions, in the two countries, and beyond. The membership of the Association will include: (a) sustainable development specialists; (b) lighting system and urbanization policy/decision-makers from the communes; (c) specialists from local research and academic institutions on lighting systems, on health and wellbeing, on biodiversity, and on energy conservation / renewable energies; (d) economists, sociologists, psychologists and ethicists; (e) residents from the communities of the region (incl. youth, elderly, both gender, frontaliers, unemployed); and (f) lighting architects.

2. There will be harmonised local regulations in place across the trans-border region at the municipal and regional levels to ensure the sustainability of lighting systems, in line with – and ensuring the application of – relevant national / regional / cantonal legislation (see Annex 2), but expanding upon this legislation where necessary to address local conditions and further strengthen sustainability. These regulations and accompanying guidelines will govern all outside light installations, including public, business and home lighting, and strict law enforcement measures will be taken by local authorities to ensure their implementation (e.g. through regular night rounds carried out by municipal police).

3. Action will have been taken to replace all sources of public lighting in the region that are the worst offenders in terms of light pollution and unsustainable lighting. As many as possible of these will simply not have been replaced, where not really needed or if located in nature-sensitive areas. Other light sources will have been subject to adjustments wherever possible (e.g. improved directionality and shielding, changing of light spectrum, etc.) needed to substantially reduce their light pollution.

4. All new investments in public lighting systems will be complying with the relevant sustainability criteria, including: (a) avoidance of light pollution, (b) provision of lighting that local neighbourhood / community residents find (through active consultation processes) to be sufficient and attractive, (c) energy efficiency, (d) featuring adaptive dimming, “smart” time- and weather-based shut-off, movement sensors, and user-activation capabilities, (d) use of autonomous solar-powered lighting (or other renewable energy sources) where feasible, (e) minimisation of material requirements, particularly of non-recycled and of hazardous materials, (f) sustainable sourcing of all materials, and (g) ensuring recyclability and recycling of all materials at the end of life.

5. A mutual / collaborative funding mechanism for sustainable lighting will have been set up for the trans-border region, from which communes, enterprises and individuals will be able to obtain the financial resources required to invest in new sustainable lighting systems – under favourable funding conditions taking advantage of any European, federal, national, regional subsidies and tax (or other) incentives available for this purpose.

6. No light source from within the trans-border region will be directly visible from the perimeter or interior of any of the region’s natural and agricultural areas, through reduced brightness, the use of appropriate spectra, and shielding and improved directionality of the lights. Any improvements made to develop green and blue corridors in order to expand and integrate the region’s natural
areas and avoid fragmentation, will be accompanied by superimposing dark, “light-less”, corridors where, additionally, no outside light from within the region will be directly visible. Wherever possible, this will include banning or strictly regulating “mobile” light pollution, e.g. by closing secondary rural roads – especially those within and nearby natural and agricultural areas – to vehicular traffic at night other than by local residents. To be successful, this will require residents’ awareness and participation. The progressive introduction – and eventual ubiquity – of driverless vehicles and related mobility services will be contributing to much-reduced mobile light pollution, given that such vehicles will require only minimal lighting – not for guidance, but only to be seen themselves by pedestrians and cyclists. To be better seen, cyclists at night will need to conform with regulations that foresee all-side reflectors and head-, back lights on the bicycle, as is the case in countries such Austria, Denmark and Germany.

7. All of the communes in the trans-border region will have adopted measures to further reduce and restrict light pollution at night – including crepuscular- and dawn- as well as off-peak-time lighting – through light shut-offs, dimming and the use of movement sensors and user-activated lighting systems. This will ensure that lights are not on when they are not needed.

8. To the maximum extent possible, measures will have been adopted to further the security of citizens against crime and other dangers, avoiding any reliance on continuous, full-strength lighting. These measures may include: (a) enhancing “neighbourhood watch and support” schemes, (b) lighting systems activated by movement sensors, (c) quick and easy danger-alert systems based on mobile devices automatically providing location data, and (d) an “ultra-rapid response” system for citizens under threat, through police teams supported by advance drones, neighbour alerts and interventions, etc. Additionally, social control is important. Persons who are especially vulnerable for victimization may be offered special training for self-defense and guidance on building self-confidence, as needed. Moreover, from young age, children need to be raised to protect the weak, stand-up to bullies and learn how to deal with aggression and violence. The problem is not so much the need for artificial light at night as it is the need for fostering altruism, collaboration and a caring society.

9. Residents of the region will be much engaged in “light-less” trans-border night-time activities, either individually or in small organised groups, including, e.g.: (a) star-gazing and astronomical pursuits, (b) night-time visits along certain authorised nature paths for wildlife observation, etc., (c) cultural activities such as “night-sky” music concerts and theatrical events, storytelling and art exhibitions, and (d) night-time visits to historic villages, towns and locations where non-polluting, attractive lighting systems have been installed. The visits along authorised natural paths will take place mostly in small guided groups under natural lighting (i.e. moonlight) or, as advisable, using special spectrum lights (red lights?) known not to disturb local fauna. Eco-tourism services to the region, will have increased substantially to also take advantage of such activities, linked to existing tourism services (e.g. Divonne’s spa / cure) and other recreational activities attracting outsiders. This will be especially true if communes in the region earn the “villes et villages étoilés” or “Dark Sky” certifications of local environmental associations.

10. There will be widespread awareness by the population of the region about the importance of, and the need for, sustainable, non-polluting lighting, and a high level of generalised support for the measures and approaches described above. Forums will be organised regularly to facilitate and actively encourage community residents to exchange views on issues relating to sustainability,
including for lighting systems, and to participate in the related decision-making processes. Mechanisms will have been set up to encourage and facilitate collaboration amongst community residents across the region in promoting sustainable lighting (and living, in general) and in finding solutions to any problems that may arise in this regard, particularly within their own homes, neighbourhoods and communes. Change management methodologies can be included such as co-creating a shared vision or using construction of disagreement (Viveret method)238. Cities, villages and neighbourhoods can generate creativity and innovation and become “change labs”, i.e. sites of experimentation for sustainable living239.

Ideally, this scenario for sustainable lighting in the trans-border region will be accompanied by similar actions in other regions (both nearby and far), in addition to a range of broader sustainability measures particularly oriented at strengthening and protecting biodiversity, including, for instance: (a) expansion and integration of natural areas to facilitate and promote migrations of species across large spaces – eventually across the whole of the European continent; (b) ensuring sustainable agriculture and gardening practices in the region, including the elimination of chemical fertilisers and pesticides in favour of bio-agriculture, permaculture, etc. that does not harm fauna and flora; (c) encouraging residents to create nature-friendly gardens (plants, trees, etc.), and to open their gardens to the free movement of fauna large and small, thus expanding the range of biological corridors into more urbanised zones (where hunting would be prohibited); (d) creating as many as needed secure fauna crossing points over roads, for danger-free migrations; and (e) reintroducing “lost” species, to the extent possible.

(B) Current state and constraints to moving to the desired vision

This paper has identified the current state in relation to the above vision, as outlined for the cases of Divonne and Mies. Despite their particularities, these two communes share many features with others in the region and could be considered to be representative of the region as a whole.

The question now is: which are the constraints and barriers needed to be overcome in order to achieve this vision? These can be summarised as follows:

People and their values – the greatest challenge

Getting people to develop a balanced perspective on lighting – as for any aspect of sustainability – is critical to efforts to achieve change, as expressed by the above vision. Even if one would be interested to live a sustainable lifestyle, there is often a time gap between awareness and action. Social psychology refers in this regard to beliefs, attitude, motivation, knowledge and lifestyle that can explain the difficulties people experience to engage in sustainability or positive change240. People will need to want it, for it to happen. Here are some of the peoples’ paradigms and values that pose the greatest barriers, and that need to be overcome:

1. **Paradigm No. 1: Light pollution? Never heard of it.** There is insufficient awareness amongst many people as to the nature and dangers of light pollution. Many people do not realise the problems that too much light at night can cause to their health, let alone to a distant natural world.

---

238 Cattiaux, S. (2012)
239 Consensus (2015)
240 Example is drawn from engaging in environmental protection activities in relation to ethical considerations. See Bonnefoy, B. (2017)
2. **Paradigm No. 2: “The moving baseline”**. Many people have no experiential reference point to help them to understand what they are missing when one talks about, for instance, “the beauty of the Milky Way” or “communing with nature”. Thus, they cannot realize what light pollution is stealing from them. This is also noteworthy since most of us can still see some of the familiar star constellations we know from childhood.

3. **Paradigm No. 3: No lights on? I’ll get robbed or crash my car!** Irrational fears of the darkness and feelings of insecurity make it impossible for many people to envisage moments when it may be dark outside. They want to be able to see what is out there, all of the time. The problem of crime can be exaggerated by people who suffer from insecurity and need to feel always in control, and hence who believe that strong and continued lighting is the best deterrent.

4. **Paradigm No. 4: Turn on the beautiful lights!** Some people just love lights, and wish to see everything brightly illuminated, whether it is their home garden, a shopping district, a monument, a park or a public garden. There may often be a cultural dimension to this attraction for lights.

5. **Paradigm No. 5: I can do nothing. It’s the Government’s responsibility!** Other people may recognise that light pollution is an issue, but feel that they can do nothing about it and that it’s the government’s responsibility to resolve the problem. They remain passive.

6. **Paradigm No. 6: The others are not doing anything either!** These people may also be vaguely aware about light pollution, but again feel that it is not their responsibility to become involved because, after all, no one else they know is involved either. This is the standby group, waiting for others to act first.

7. **Paradigm No. 7: Light makes me feel modern, civilised.** The contrary, absence of light, is seen as returning to a more primitive world.

**Institutions and the legal system**

Governments at different levels can sometimes also be barriers to change, and the legal systems may also either create impediments or provide incentives and funding to competing alternatives (for instance, saving energy at all costs, even if this results in greater light pollution). It is important to ensure sectoral policy coherence, i.e. legal frameworks concerning environment, agriculture, construction and urbanization, transport, waste, energy transition, etc. so that anti light pollution measures are given the full attention they require. Furthermore, these national legal frameworks should consider relevant existing international treaties to provide multilevel coherence, being in line with the respective EU Directives and the Convention of Biological Diversity, Minamata Convention to phase out mercury products, Basel Convention on the Transboundary movement of hazardous wastes and their disposal (for light bulbs and other lighting technologies, etc.). It seems safe to say, however, that the national governments in both France and Switzerland seem to be committed to dealing with light pollution seriously. The French Minister for Ecological Transition and Solidarity announced on 18 October 2017 a series of measures that the government will take to tackle light pollution, including new legislation, regulations and standards. The Swiss Ministry for the Environment has published guidelines for local

---

241 République Française, Ministère de la Transition écologique et solidaire (2017b)
Tackling Light Pollution for Sustainability – An Approach for the Vesancy-Versoix Corridor

governments and others on how to reduce light pollution\(^{243}\), but these as yet do not have the force of law. Government policies, laws and regulations need to be coherent to ensure that implementation is carried out efficiently. This coherence has to be maintained across countries as well; signing contracts as done for the eight corridor contracts of the Franco-Valdo-Genevois Agglomeration Project\(^ {244}\) appears to be a good strategy for cross-border collaboration. The full range of relevant laws and regulations of the two countries is given in Annex 2. Ideally, the two countries – or at least the regions and cantons forming part of the Greater Geneva area – would harmonise their legislation and / or regulations to facilitate trans-border cooperation.

Much of the enforcement, however, needs to take place at the Commune level. Contacts met during the course of this project with municipal authorities of Divonne and Mies indicated a willingness to deal with the problems of light pollution. This willingness will need to be converted into actions. It important to consider here, as an example, the village of Sauverny in the Pays de Gex, very nearby Divonne. It has recently become one of the large and growing number of towns and villages in France that turns off its street lamps at off-hours in the deep night. Its street lamps are also not bright and are well-directed.

In addition to governmental bodies, a number of other institutions can either constitute barriers to change or facilitate and encourage it. Organizations mentioned earlier such as ANPCEN and FRAPNA in France and ProNatura in Switzerland are vigorous anti-light pollution campaigners. To date, 300 communes in France have signed the volunteer ANPCEN charter to reduce light pollution. These 300 communes represent about 7% of the population. The progress is encouraging as the Ministry for Ecological Transition and Solidarity has adopted combatting light pollution as one of his urgent priorities, with measures being enforced in 2018. It seems to be only a question of time of when reaching the critical mass of 11% to 14% of the population. On the other hand, bodies concerned with, for instance, the installation of public lighting systems, road services, outdoor entertainment, advertising, mass tourism, security services and others may have an interest in defending the continuing presence of substantial outdoor lighting. These organisations will need to be converted to the cause of sustainability in lighting systems by helping them to understand how this is in their long-term interest also.

**Economic and financial barriers**

Economic and financial barriers to changing in favour of sustainable lighting systems include:

1. Limited funding available in municipal budgets to provide for new investments in sustainable, non-polluting lighting systems.
2. Competing priorities for these budgetary resources.
3. Limited financing available at favourable conditions to invest in sustainable lighting systems.
4. Difficulties in obtaining the full information needed to carry out comprehensive life-cycle-costing (LCC) analyses.
5. Difficulties in valuing the ecosystem services obtained from protecting biodiversity through the reduction of light pollution. This applies if we are to make a valuation comparison between what it will cost to reduce light pollution in order to compare it to the value we gain from protecting biodiversity (under a weak sustainability scenario).

---

\(^{243}\) Office federal de l’environnement (2017a)

\(^{244}\) Grand Genève (2016)
Tackling Light Pollution for Sustainability – An Approach for the Vesancy-Versoix Corridor

6. Technologies that provide for lower levels of light pollution are currently more expensive to purchase than more polluting technologies (e.g. less polluting narrow-band amber LED lights are more expensive than standard white-light LED lamps).

Technological barriers

Technological barriers to be overcome involve, for instance:

1. Remaining scientific uncertainties regarding which spectra / lighting technologies are the most convenient to use in different circumstances to avoid harm to different species
2. The most convenient technologies to tackle light pollution are usually the most expensive.
3. Some promising technologies are not yet readily available in the market (e.g. user-activated lighting start-up, using mobile devices or RFID technologies)
4. Low energy cost technologies such as LEDs can create a rebound effect, whereby savings obtained encourage the purchase of more (polluting) lighting systems than would otherwise be the case.
5. There may be incompatibilities between certain technologies that will not allow them to be used together.

(C) Strategy to overcome the barriers and achieve the vision

Measuring progress: the importance of indicators

Understanding light pollution is not easy, as it comes about in many different forms and most are not easy to define, describe or measure. And yet, if light pollution is not measured, then it cannot be tackled effectively as there will be no way of knowing whether progress is being achieved or not.

The most direct and accurate way of measuring light pollution in an area is through the Analysis of mapping tools for monitoring the extent of light pollution.245,246 These mapping tools show how much light pollution there is in the sky above a given location, thus making it difficult by varying degrees to view the stars. This mostly measures sky glow, the halo of light above population centres. However – since these maps involve a fluctuating range of merging colours reflecting the different light pollution intensities – they may be difficult to use in pinpointing the actual sources of light pollution, let alone in knowing what is specifically causing it and in being able to precisely measure changes. Therefore, additional “proxy” indicators can be used to help identify the amount of light pollution at a given location along with its causes and eventually (in some cases) also its potential impacts. A reasonably comprehensive list of these indicators is as follows. The first four indicators are recommended by the French Association nationale pour la protection du ciel y pour l’environnement nocturnes (ANPCEN), whereas others are drawn from additional sources and from the author’s reflections.247

---

246 Falchi, F, et al. (2016); The new world atlas of artificial night sky brightness. Fabio Falchi, Pierantonio Cinzano, Dan Duriscoe, Christopher C. M. Kyba, Christopher D. Elvidge, Kimberly Baugh, Boris A. Portnov, Nataliya A. Rybnikova and Riccardo Furgoni. To see the atlas, open the following on Google Maps / Google Earth: http://pmd.gfz-potsdam.de/contact/NewWorldAtlas_ArtificialSkyBrightness.kmz
Tackling Light Pollution for Sustainability – An Approach for the Vesancy-Versoix Corridor

The four ANPCEN recommended indicators are reflected in Figure 9 below.

1. **Average luminous intensity of the lighting installations** in lumens per km of streets / roads and / or per m² of surface area. This can be seen from three perspectives (the latter two have been added and are not in the ANPCEN indicators):
   - As emitted by the lamps: ANPCEN ratings A (green) – G (red) from < 75 to > 450 lumens / km
   - At the base of the street-light poles
   - Midway between street-light poles

2. **Average orientation of the lighting installations** in terms of degrees of lamp light emissions above the horizontal level.
   - ANPCEN ratings A (green) – G (red) from < 0 ° to > 30 °

3. **Average spectral distribution of the lighting installations**, based on a colour classification of lamps that takes account of their light emissions in the UV, blue and green spectra (considered harmful to living creatures): ANPCEN ratings A (green) – G (red) as follows: A: Low pressure sodium (LPS); B: High pressure sodium (HPS); C: Warm LED (< 3,000 k); D: Fluorescent (< 3,000 k); E: White sodium and Neutral LED (< 4,100 k); F: Metal Halide (MH) (< 3,000 k); G: Halogen, MH and Fluorescent (> 3,000 k), and Cold LED (> 4,100 k).  

4. **Average power consumption of installed luminaires** in Mw/hours (the second has been added and is not in the ANPCEN indicators):
   - Per km of streets / roads or per km² of surface area
   - Per inhabitant

5. **Total street length where luminaires are installed** (in km or m):
   - Grand total
   - In urban areas
   - In peri-urban areas
   - In agricultural area
   - In forested / meadow / natural areas

6. **Total illuminated surface area** within 100 m of a luminaire (in m² and as a percentage of the total area) including:
   - Grand total
   - In urban areas
   - In peri-urban areas
   - In agricultural areas
   - In forested / meadow / natural areas

---

248 Despite the spectral advantages of LPS and HPS, they consume more energy than LEDs and have a low Colour Rendition Index (CRI), meaning that they do not show the correct colours of objects being illuminated (particularly LPS). Furthermore, they both take time to turn on, and cannot be dimmed, which greatly limits their usefulness for lighting systems where variability of intensity and quick on-off capabilities are desired. Regarding LEDs, the original white-coloured LEDs are considered harmful to humans and to the biosphere. More recent evolutions of LED technology have led to options that are much less harmful: Phosphor-converted amber (PCA) LED and, particularly, Narrow band amber (NBA) LED. These are more costly than standard LEDs, but as their introduction expands they are expected to become less expensive. For more information: [https://www.noao.edu/education/QLTkit/ACTIVITY_Documents/Energy/TypesofLights.pdf](https://www.noao.edu/education/QLTkit/ACTIVITY_Documents/Energy/TypesofLights.pdf)
Figure 9: Four ANPCEN labels

Source: ANPCEN
7. **Total number of luminaires installed** (and as percentages of the grand total):
   - Grand total
   - By categories of luminous emission intensity by the lights (in lumens)
   - By categories of luminous intensity on the ground (in lumens / m²)
     - At the base of the street-light pole
     - Midway between street-light poles
   - By categories of spectral wavelength (see Indicator No. 3 above)
   - By categories of lamp cut-off type (shielding of the light)
     - Full cut-off
     - cut-off
     - semi cut-off
     - no cut-off
   - By types of lighting control being implemented (may add up to more than 100%)
     - With no lighting controls
     - With astronomic controls
     - With biological calendar controls to reduce lighting at critical times of biological activity (migration/breeding/foraging)
     - With environmental conditions controls (in response to weather, luminosity, ground reflectivity, etc.)
     - With dimming
     - With timing on-off-on controls
     - With activation using movement sensors
     - With other kinds of activation controls (e.g. push-buttons, RFIDs, mobile phone controls, etc.).

8. **Average age of installed luminaires**

9. **Total number of hours of illumination** (calculated by adding the numbers of hours of illumination for each lamp)
   - With full strength lighting
   - With 50% or less dimming
   - With more than 50% dimming

Light pollution in outdoor lighting can have many negative impacts, including on human health and on biodiversity, energy consumption and greenhouse gas emissions (depending on whether renewable energy is used), and on public expenditures. The level of energy consumption is already shown through Indicator No. 4, above. The three indicators below will serve to assess: (a) the assumed potential impact of light pollution on biodiversity in natural areas; (b) the GHG emissions and contribution to climate change; and (c) municipal efforts to upgrade the lighting system and improve efficiency.

10. **Number of points of street lighting that can be observed from the perimeters of natural and agricultural areas.** (Obtained from physically monitoring light installations by walking or driving around the natural areas.)

---

249 *Der Spiegel* (2009)
11. **Average fossil-fuel sourced power consumption of installed luminaires** in Mw/hours:
   - Grand total
   - Per km of streets / roads or per km² of surface area
   - Per inhabitant

12. **Municipal expenditures on public lighting** per year (and % increase or decrease)
   - Grand total (and per inhabitant / resident)
     - Investments in new lighting systems
     - Expenditures on electricity consumption (also average per luminaire)
     - Expenditures on maintenance and repair (also average per luminaire)

The following two indicators can be used to review the effects of light and light pollution on road accidents and on security against crime. They will be most useful but difficult to measure, although the effects are well known from past research.

13. **Numbers of road accidents** by hour of day and of night, by location and by type of accident (e.g. involving pedestrians, cyclists, wildlife, etc.), while specifying wherever applicable if the accident is considered to have happened primarily because of:
   - Insufficient illumination
   - Excessive illumination
   - Factors other than the level of illumination

14. **Numbers of crime incidents** by hour of day and of night, by location and by type of crime (e.g. theft, violent aggression, etc.) specifying wherever applicable if the crime is considered to have been facilitated by:
   - Insufficient illumination
   - Excessive illumination

Broader understanding of citizens’ perceptions of the problem of light pollution and its consequences, and of actions being taken by the communal authorities to improve understanding and encourage community actions in this regard can be drawn from the following indicators.

15. **Citizens’ perceptions** – to be obtained through a yearly online survey, but also (where and when relevant) before / after installation of new lighting systems:
   - Regarding light pollution, quality of sleep and health
   - Regarding light pollution and its effects on biodiversity
   - Regarding light pollution and appreciation of the night sky
   - Regarding light and security
   - Regarding light and road safety
   - Regarding light and economic equality

16. **Number and nature of actions taken by municipal and other authorities / bodies to increase awareness** amongst the population about light pollution and its effects, particularly actions related to bringing together members of the community to discuss lighting and light pollution problems and to jointly work out solutions.
17. **Improved local municipal regulations and actions taken** to reduce light pollution. These may be gauged (in the case of communes in France) by adopting the APCEN Charter to combat light pollution and / or by being designated by APCEN as a “Ville ou village étoilé”.

To the extent possible, these indicators should be adopted and kept updated at least once per year by municipal authorities (or the relevant bodies concerned with collecting this information) and made available to citizens through the communes’ websites for their own information and to encourage their participation in the decision-making processes.

**Creating awareness and changing minds**

We have seen that the greatest barrier to achieving change for the vision to be realised are the paradigms that keep people’s minds fixed on the desire for abundant light. These paradigms may be based on fear – which will be the most difficult to overcome – or other emotional reasons such as pride and attachment to a certain way of life. Alternatively, people may feel that they have already too much on their minds, and that they have no time or inclination to deal with other new issues. They may not be aware of these issues, or they may just not want to be aware.

A communication and persuasion strategy needs to be developed that addresses these different paradigms, at different levels:

- **Information.** At the most basic level, some people may only need to know the facts to be persuaded of the need for change. They can discover the facts by listening to a radio broadcast, by watching a documentary on TV, or by reading an article in a magazine or in an attractive flyer that they find in their mailbox.

- **Co-creating a shared vision.** This strategy refers to creating the future we individually and collectively want. The goal is to “… unearth shared ‘pictures of the future’ that foster genuine commitment and enrollment rather than compliance.”

  The aforementioned association or agency defines individually and with citizen participation the following:

  (a) what is the purpose of having a clear and shared vision;
  (b) what is the purpose of implementing some step-by-step measures;
  (c) what is the definition of success for active members (considering the four sustainability principles);
  (d) what is the goal we want to achieve together;
  (e) what are the intentions of those involved;
  (f) to imagine a date in the future (e.g., in 1 year, 5 years, 20 years) with proposals that will have been implemented and to imagine what concrete benefits the changes brought to the region; and
  (g) a concept map of today’s elements and a visual picture of the desired future.

---


251 Use past tense or future perfect tense (“what will have happened”). Coaching ideas for example, see Swanson, B. (2012)
• **Construction of Disagreement / “Agree to Disagree”:** It is obvious that there are various and different perspectives on the Grand Genève region’s purpose, its policies, procedures and daily operations amongst different stakeholders. We can use the Viveret methodology on constructing disagreement by using our different standpoints as assets. This entails not to find agreement on the smallest common denominator, but on getting clear and formulating disagreement.\(^{252}\)

• **Empathy.** Other people may be persuaded through emotional empathy. They need to be able to identify with the problems faced by someone (e.g. a person who has become ill) or something (in our case, for instance, a creature suffering in the forest), and this will drive them to try to help with resolving the problem. Empathy can be built up also through providing information oriented in an emotional way, or by identifying with a particular person or situation, for instance that of a person known through a discussion forum, or through a character in a drama, a film, a book or in a musical play. Having been driven – through working on this project – to the issues of light pollution and to the need to convince people of the need for change, the author has become involved in the creation and production of a musical play on light pollution that will be performed by school children called “The Beauty of the Night” (see Annex 8). The purpose of this musical is to reach the minds and hearts of people in the region through music, rhyme and – most importantly – their own children.

• **Motivation.** Some people just need a nudge to become motivated. They can become motivated, for instance, through seeing a well-known person – e.g. an actor or singer, or activist – or a person in their entourage – a family member, a friend – become involved. Creating opportunities for motivation will be an important part of the communications and persuasion strategy, for instance if their child, or a child of a friend, is acting in a musical play.

• **Paradoxical thinking.**\(^{253}\) In case of high resistance to changing societal beliefs and attitudes (i.e. to keep these in a homeostasis\(^ {254,255}\) as “things were always done like that”), a paradoxical thinking strategy can be applied. This entails encouraging resistance to persist and to avoid the need for defense mechanisms. According to the theory of paradoxical thinking strategy, this would value the identity of those resistant to change. The new information provided – though of extreme content - to the change resistant population is hence in line with their beliefs and attitudes. If and once the situational absurdity becomes obvious, the targeted high resistant group could come oneself to conclude that the current situation is irrational. When this group moves towards the desired direction, unfreezing of some socio-psychological barriers has happened.

• **Self-interest.** Other people may only be convinced because there is something in it for them, e.g. a business opportunity, a consultancy contract, or an opportunity to be recognised by others and congratulated.

---

\(^{252}\) Methodology “Construction des desaccords” developed by French philosopher Patrick Viveret to transform disagreements into collective intelligence. See Cattiaux, S. (2012)

\(^{253}\) Hameiri, B. (2015)

\(^{254}\) Tendency of a biological system to resist change and to maintain itself in a state of stable equilibrium.

\(^{255}\) Integration Training (2010)
**Tackling Light Pollution for Sustainability – An Approach for the Vesancy-Versoix Corridor**

- **Ethics and values.** Finally, ethics can become an important driver if the values of people are oriented towards, for instance, protecting the weak and ensuring fairness and justice, etc. If they see light pollution as being unfair to fellow humans or to creatures deserving protection, they may act.

- **Experiencing changed reality.** The best way for people to appreciate reduced artificial light at night (ALN) that eliminates light pollution is to develop demonstration projects that one can go to for observation, learning, discussion and understanding. This could include, e.g. creating ideal lighting system demonstrations in certain streets in towns or villages, in addition to complete ALN shut-off areas (except for weekends to accommodate late night home comers using public transport), which already exist in villages like Sauverny or in the Jura mountains. The same could be done for pilot guided nature and astronomers walks, etc.

**Identifying change leaders and building teams**

Successful change also requires leaders and teams to co-create knowledge and together find solutions. It will be important to find such leaders and build the teams with concerned stakeholders in the region. Establishing roles for team members will be important to ensure effectiveness. These roles may include:

- **Leader** – holds the vision
- **Coordinator** – creates the project structure and the implementation strategy
- **Creator** – looks for innovative solutions
- **Network builder** – manages the external communications
- **Team players** – internal social interactions
- **Perfectionist** – looks into the details and ensures quality

A priority should be to build trans-border teams for developing pilot projects to tackle light pollution across the concerned areas of France and Vaud / Geneva, in order to develop trans-border collaboration.

**(D) Action plan priorities**

In the following table, are illustrations of some of the possible actions that stakeholders might wish to adopt as and when best suited – within the framework of the above overall strategy – in their efforts to reduce light pollution and ensure sustainable lighting systems. These actions are grouped according to SDG targets, in line with the priorities established in Chapter 3, which reflect levels of impact on overall sustainability.

Either directly or indirectly, the focus of these suggested actions is aimed at advocating that artificial light at night be used only in the precise amounts in which it is needed, only at the precise places where it is needed, and only at the specific times when it is needed; and, of course, employing the light spectra that is shown to be most suited to avoiding – or at least minimising – harm to living creatures.

Some additional actions are also included below that are not specifically related to light or light pollution, but which complement these as part of efforts to secure a sustainable future for our planet. Some of the actions described below are straightforward, and easy to implement.
Table 7: Prioritised actions to reduce light pollution, grouped by SDG targets

<table>
<thead>
<tr>
<th>Light pollution action</th>
<th>SDG targets</th>
<th>Types of potential actions relating to light pollution</th>
</tr>
</thead>
</table>
| 1                      | 132 15.5    | • Avoidance of lighting wherever possible nearby and inside natural areas, and ensure otherwise that light is not directed towards natural areas. *Avoid and minimise light pollution everywhere else through appropriate lighting systems and improved awareness and education*  
  • Reforestation of light-free urban, sub-urban, rural areas wherever possible, including eventual re-conversion of agricultural lands  
  • Light pollution-free dark bio corridors ("trames noirs") covering public, industrial land and private gardens and providing buffer zones around protected areas and the biological corridors themselves  
  • If the CBD Aichi Targets are to be met, conventional agricultural land is to be converted into organic land. This requires awareness raising and financial incentives for farmers. |
| 2                      | 210 11.2    | • Since transport infrastructure impacts on the fragmentation of habitats (the biggest risk for land-system change), measures need to ensure that they do not pose barriers to green/blue/dark biological corridors and their buffers zones. Thus, efforts to build adequate crossings for fauna of all kinds (large and small) need to be strengthened and accelerated for the benefits of the animals and of the drivers who may be subject to accidents. These biological corridors need to be interconnected to allow movement of fauna locally, regionally and across the continent.  
  • Local sustainable development strategies need to include light pollution combative measures in public and private spaces, while ensuring that those in need can move around safely.  
  • Besides smart, time-based and optimally directed light technology and safe, affordable, accessible and sustainable means of transport, security and safety aspects must include public education to address reasons and solutions to insecurity (e.g., often women and elderly persons feel more insecure when using public transport at night) 256,257. It is crucial to foster empathy and wide-spread civil courage to step in for those facing violence or criminal behaviour, and to increase the self-confidence of potential victims (likely to be a more effective deterrent than public lighting). This also means combating violence at home and increasing social controls, as studies have shown that victims are more likely to be violent in public, themselves258.  
  • Working groups on lighting systems for roads should be set up, including traffic engineers, designers, urban architects, ecologists, sustainability experts and residents, when planning or modifying roads and lighting plans. |

256 Culet, J (2017)  
257 RTS Radio Télévision Suisse (2017)  
258 Fox, K. et al. (2009)
Tackling Light Pollution for Sustainability – An Approach for the Vesancy-Versoix Corridor

- Measures to reduce light pollution on roads can help to make them safer by eliminating blinding light glare, e.g. directing light only downwards, avoiding excessively bright lights, distributing light efficiently and homogenously, etc. Use of reflectors with well-engineered optical shapes such as “cats’ eyes” instead of energy-using lighting can in many cases also be effective, safe and less expensive.
- Mandatory security measures for bicycles, wheelchairs and others should be instituted, including lighting, reflectors at night and pathways physically separated from car traffic.
- Better addressed lighting needs across residential populations means lighting spectrum could be adapted to gender and age differences due to their different sight capabilities (e.g., using lighting adapted to older persons’ needs around retirement homes to foster mobility and social inclusion).
- Light pollution can be reduced by restricting secondary rural roads at night to only local traffic, requiring through-traffic to use the main roads.
- Research is inconclusive concerning the impact of changed lighting conditions on driving behaviour and accidents. Drivers appear to not adapt their driving speeds to reduced visibility. At the same time, drivers tend to increase speed with more lighting. Many other factors come to bear, e.g. weather conditions, gender and age of drivers, drowsiness, consumption of stimulants and distraction, etc. Thus, changing driver behaviour through e.g. stricter driver learning, reduced speed limits, better signalisation and law enforcement appears to be a better strategy than increasing lighting.
- Over the longer term, the introduction of self-driving vehicles will mean that bright headlamps will not be needed – only enough light for the vehicles to be seen by pedestrians and cyclists, etc. To the extent that ubiquitous mobility services based on self-driving vehicles replace privately owned cars, the numbers of vehicles and their lights on the road will be substantially diminished.

### Effective institutions

- Harmonization of legal frameworks encompassing environmental dimensions
- Institutions are critical for organising any and every human activity. Their public policies are intended to respond to social issues. Weak policy is often due to fragmented authority and responsibility, or unresolved conflicts.
- There needs to be greater awareness of the extent and impacts of light pollution as a call to action across society, relevant public institutions, NGOs and the private sector concerned with sustainable development, city / town governance and lighting systems.
- Institutions dealing with light pollution need to be strengthened, build greater synergies and collaboration, and enhance citizen participation.

---

259 To protect amphibians - worldwide the species most in danger of extinction - the canton of Geneva opened a new natural reserve with leisure opportunities. To do so, the canton permanently closed a road used by 6,000 cars per day. The road closure involved increase in time and CO2 emissions for cross-border traffic. See: Leroy, R. (2011)

through inclusive and collaborative decision-making and through community development.

- Institutions need to serve as role models for better public education, i.e. visibly display attitudes supportive of sustainability.\(^\text{261}\)

- Multilevel governing capacities for environmental policy and implementation need to be improved in parallel at city and local, regional, national and international levels,\(^\text{262}\) using a consensus-based, transdisciplinary approach encompassing science, economics, psychology and other relevant fields.

- Traditional command-control public policies such as the polluter-pays principle, rule of law, transparency and accountability need to be supplemented with citizen-centred policies and incentives, e.g. information disclosure and access to statistical data at the local, regional and national levels; adoption of comprehensive local and regional planning rooted in long-term sustainability goals; and educating citizens to assume responsibility and accountability for individual and group behaviour, including building on common values for preservation and intergenerational justice.

- Institutions and society need to enhance their sustainable development skills, e.g. critical thinking, systems analysis, interacting in heterogeneous groups, co-creating knowledge, value-building, anticipating and mitigating risks, and ensuring responsibility and accountability.

- Institutions need to have the necessary resources for efficient and effective functioning, including human and financial resources and low-energy consuming technologies.

- Local sustainable development strategies need to include light pollution combative measures.

---

4 168 2.4 Food production/agriculture

- Collaboration is needed between farmers’ associations, ecologists, scientists, agronomists, and different public authorities regarding the protection of food producing lands from light pollution.

- If the CBD Aichi Targets are to be met by 2020,\(^\text{263}\) conventional agricultural land is to be converted into organic land. This requires awareness raising and financial incentives for farmers.

- Need to include light pollution reduction policies and measures into sustainable, organic agriculture and pisciculture policies and practices

- Need to protect natural and agricultural (and private properties / public shared gardening) areas from ALN

- Strengthening of regulations and law enforcement to protect fish breeding grounds and young fish so as their numbers can rehabilitate; this also includes working on providing re-naturalized and secured habitats for different fish species

- When using light for purposes of pest control, ensuring the moderate use of light spectra that are species-specific, to ensure continued naturally balanced pollinator services

---

\(^{261}\) Wiek, A. et al. (2011)

\(^{262}\) Vig, N. and M. Kraft (2016)

\(^{263}\) UN Convention on Biological Diversity (1992)
### Tackling Light Pollution for Sustainability – An Approach for the Vesancy-Verboix Corridor

<table>
<thead>
<tr>
<th>5</th>
<th>162</th>
<th>4.4</th>
<th>Technical / Vocational Education and Training (TVET)</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Fostering of ecosystems services provided by nocturnal and diurnal pollinators, e.g. bats, night and day flying insects as critical pollinators</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Introduction of systems thinking at schools and agricultural institutions, if not already done</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Provision of incentives for organic urban gardens, for sharing of public spaces at community level, with revolving responsibility</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Local business opportunities and entrepreneurship for Dark Sky and health spa tourism</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Educational institutions will rapidly need to provide systems thinking, co-creating with stakeholders resistant to change to find solutions best adapted to local situations.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Creating conditions that attract people with the necessary technical, vocational, management and leadership knowledge and skills, including transversal sustainability competencies (systemic, strategic, normative, prospective and interpersonal) to design, build and implement systems in the region that are fully compatible with sustainable development. This implies work in multidisciplinary teams from various backgrounds with autonomy and responsibility. This happens only if there is a generalized commitment and political will to move in this direction, providing the necessary incentives, standards, guidelines, etc.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Local institutions need to quickly offer TVET programmes that embed environmental challenges and sustainability knowledge into all disciplines rather than creating isolated specialized “silos”. This creates a common understanding of sustainability issues and approaches.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Awareness / participative information campaigns (e.g., workshops, community engagement projects, photography competitions, informative movies &amp; info package for new residents and newsletters) need to be carried out to help the general population better understand the issues of sustainability, planetary boundaries, consumer behaviour, light pollution, etc. and to co-develop solutions.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Awareness raising through making light pollution a topic for discussion and in art and cultural exhibitions.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• All of the above considers light pollution and lighting systems as an integral part of sustainable development solutions.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>6</th>
<th>159</th>
<th>9.4</th>
<th>Infrastructure / clean</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Providing sustainable financing and investment and public-private partnership opportunities and foster NGOs to foster education in sustainable finance. This can also include local crowd-funding solutions, networking places.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

264 See community engagement, photographic competitions, research as an example at University of Hong Kong (2014)

265 For example, capacity building on non-finance metrics for sustainability, green and carbon accounting, environmental markets, project finance, sustainability investing, and impacts of environmental, social, and governance issues on capital markets, concepts on how environmental commodities markets regulate polluting industries and how to provide incentives for encouraging desired behaviors. See: Columbia University, Earth Institute (n.d.)

266 Innovate4Climate is supposed to become “…the place where finance, markets and technology meet to accelerate climate action…” and is “…a new global dialogue of government, multilateral, business, banking and finance leaders focused on shaping the next generation of climate finance and policy instruments.” [...] As part of the Paris Agreement on climate (COP21), national climate action strategies (Nationally Determined Contributions or NDCs) submitted require USD 23 trillion investments in
**Tackling Light Pollution for Sustainability – An Approach for the Vesancy-Versoix Corridor**

<table>
<thead>
<tr>
<th>7</th>
<th>120</th>
<th>11.1 Affordable housing</th>
</tr>
</thead>
</table>
| **technology** | • Enabling scaled-up, climate smart, low-carbon investments, which offset higher upfront costs through efficiency gains and fuel savings\(^{267}\)  
  • Provision of incentives for greater efficiency in materials, energy, water, pollution reduction efforts, aiming at more sustainable product design, use, and disposal, using integrated management and supply chain control  
  • Pricing of negative environmental externalities, such as polluting emissions and the inefficient use of scarce natural resources\(^{268}\)  
  • Industry to drive innovation\(^{269}\) and to use internationally agreed pro-environmental-protection and resource-conservation sustainability standards based on dematerialization (e.g., less, shorter and lighter light poles) and circular economy, thus preserving natural capital  
  • Application of international standards and move to a polluter-pays / true cost accounting production and consumption scheme, which requires product (service) life-cycle assessment  
  • Fostering of functional service economies for eco-designed products and consumption patterns, e.g. business to consumer (B2C) eco-user niche markets providing carefully designed sustainable services with business models based on environmental values (leasing, sharing)  
  • The move to LEDs is already leading to cleaner technologies as some of the worst pollutants of earlier lighting technologies are being eliminated. But, the most energy efficient white-blue (>4,000 k) LEDs are bad for the environment. LED lights are also not pollution free. Particularly, the production of some LEDs involves the use of some hazardous materials, which can be removed but at a higher cost. Thus, as clean technologies improve\(^{270}\), the remaining pollutants in LEDs can be eliminated, improving even further the case for their use.  
  • Public lighting should be sustainable eco-green\(^{271}\) and take place in stages to allow introducing the best technological option, finding a balance between environmental friendliness, social needs and economic thinking.  
  • Making use of energy-consumption friendly Apps, ICTs, Internet of Things (providing sufficient cybersecurity) for users to better manage and operate public and private lighting |

---

\(^{267}\) Innovate4Climate (2017)  
\(^{268}\) OECD, WORLD BANK, United Nations (2012)  
\(^{269}\) See lighting industry efforts and TALQ consortium under: Lokhoff, G. (2015)  
\(^{270}\) Ma, M. (2013)  
\(^{271}\) For green technologies to spur, the costs currently are too high, the risks are too great or the markets are too small. See: de Boer, Y (2016)
### Tackling Light Pollution for Sustainability – An Approach for the Vesancy-Versoix Corridor

- Setting up inter-generational Housing Cooperatives/Co-housing responsible for their own lighting systems & management, maintenance and energy consumption (as per certified technology standards), where each person is responsible in a revolving scheme to carry out activities to ensure the well-functioning of the coop lighting system – for which employers offer the equivalent of free hours.

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>105</td>
<td>7.3</td>
<td>Energy efficiency</td>
</tr>
<tr>
<td></td>
<td>Providing legal frameworks(^{272}) and incentives for better application of energy efficiency while including environmental considerations.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Application of taxation on production and consumption of energy (indicators needed). More research needed whether taxation should relate to production of energy, consumption or both – while recognizing that private end-users cannot bear all the costs by themselves – and ensuring that products are produced in a sustainable way.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Downshifting (lighting strictly suited to the minimum necessary need, regarding the amount, the location and the timing of light.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Adoption by modern, smart and green cities of energy-efficient non-micropollutant illumination technologies with as much environmentally-friendly colour spectrum as possible.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Significant risk reduction of the rebound effect is through better lighting systems (time, spatial, spectrum), reduction of energy consumption, and through off-peak or total shut off, dimming, movement</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Citizen participation and transforming social behaviour is key to reaching a low-carbon society</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| 9 | 94 | 12.5 | Waste |
|   | Elimination of remaining toxic waste |
|   | Recycling of materials wherever possible (avoid using much more sand as it is much rare than one would might think\(^{273}\)) |

| 10 | 87 | 6.6 | Water-related ecosystems |
|   | Avoidance of any lighting as much and wherever possible nearby water-based and adjacent riparian and terrestrial ecosystems. This means that light shall not shine on water and riparian buffer zones. |
|   | Consideration of technological and spatial mitigation measures for the sake of ecological impact into new lighting concepts by landscape planners, urban and light architects, light engineers in collaboration with ecologists\(^{274}\). |
|   | Training in systems thinking and sustainability, particularly on environment / ecology matters, needs to be added, if not yet done so, to specialized professions such as urban and landscape planning, light architecture, light engineering, etc. |
|   | Strengthening of regulations and law enforcement to protect fish breeding grounds and young fish so as their numbers can rehabilitate; this also includes working on providing renaturalized and secured habitat for different fish and other water-related species |


\(^{273}\) Peduzzi, P. (2014)

\(^{274}\) Manfrin, A. et al. (2017)
Tackling Light Pollution for Sustainability – An Approach for the Vesancy- Versoix Corridor

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th>Non-communicable diseases</th>
</tr>
</thead>
</table>
| 11 | 75 | 3.4 | • Elimination of all intrusion of public lighting systems into homes  
• Awareness raising and education of people to reduce lighting at night and use light emissions with “warm” colours, and to sleep in total darkness  
• Awareness raising and incentives for private households to use only lighting spectra that are not disturbing to human wellbeing  
• Recognition that there is a certain dependency on smart mobile devices and other electronics using blue light in many parts of the population. Business / suppliers need to ensure that devices contain elements and emit light spectra not damaging to health. This requires international standards and transparency.  
• Avoidance of excessive ALN and light trespass in public spaces; addressing different lighting needs of various population groups  
• Promotion of skygazing therapy and wellbeing / rehabilitation locations |

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th>Forests</th>
</tr>
</thead>
</table>
| 12 | 64 | 15.2 | • Avoid lighting wherever possible inside and nearby forests, and ensure otherwise that light is not directed at forests  
• Natural reforestation as much as possible to balance out against other regions that are not able to stay within the limits set by the Aichi targets  
• Avoidance of any light sources visible from within forested areas and biological corridors, either by shielding or, preferably, through shut-off and de-installation |

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th>Renewable energy</th>
</tr>
</thead>
</table>
| 13 | 48 | 7.2 | • Recognition of risk and avoidance of the rebound effect.  
• Production and consumption only from renewable energy sources that do not encroach upon natural and agricultural areas and are thus mostly installed in already developed/constructed spaces, e.g. solar roads and roofs.  
• Using natural moonlight when available as a renewable energy source at night, allowing lighting systems to be either dimmed or shut down.  
• Solar panels and wind energy can be used on autonomous (off-grid) street lamps if their power consumption is low, thus following a decentralized energy-generation strategy based on renewables. Power consumption can be reduced (see 7.3) by using low-energy consumption technology and by adopting anti-light pollution practices like dimming, movement detectors and cut-offs.  
• Options based on bioluminescent bacteria (for business displays or advertisement) are also being developed and could become economically viable one day for low energy consuming / low pollution lighting. |

---

275 Marcellin, F. (2016)
Tackling Light Pollution for Sustainability – An Approach for the Vesancy- Versoix Corridor

Appendices

Annex 1 - A systemic perspective on light pollution: causes and effects
Tackling Light Pollution for Sustainability – An Approach for the Vesancy-Versoix Corridor

Kerstin Ludwig
Annex 2 – Relevant legislation / recommendations related to light pollution for France and Switzerland

### France

Les règlements et les directives de l’Union européenne influencent le cadre legal en France e.g., Council of Europe Resolution 1776 Final version (2010) on noise and light pollution

| Code de l'environnement | Art. L.583-1 à 583-5 du code de l'environnement détaillent la manière selon laquelle ces objectifs peuvent être atteints. Des prescriptions techniques peuvent être imposées à l'exploitant ou l'utilisateur de certaines installations lumineuses par arrêté du ministre chargé de l'Environnement. Art. R.583-1 à R.583-7 définissent notamment les installations concernées par cette réglementation, le zonage permettant d'adapter les exigences aux enjeux des territoires concernés (agglomération, espaces naturels, sites astronomiques) ainsi que les principales prescriptions techniques qui peuvent être réglementées par arrêté. La loi prévoit que le ministre peut interdire ou limiter le fonctionnement par arrêté, à titre temporaire ou permanent, de certaines sources lumineuses au regard de leur nature ou des caractéristiques locales. Ces arrêtés sont pris après avis du Conseil national de la protection de la nature et ne peuvent concerner que :  
|  | • les installations lumineuses telles que les skytracers, dont le flux est supérieur à 100 000 lumens, ou les faisceaux de rayonnement laser, qui peuvent générer d'importantes nuisances lumineuses sur l'environnement nocturne de par leur intensité lumineuse ou la visibilité à grandes distances de leurs faisceaux ;  
|  | • les installations lumineuses situées dans les espaces naturels protégés désignés en annexe du décret et les sites d'observation astronomique exceptionnels, ces sites étant par définition sensibles aux impacts de la lumière nocturne.  
|  | Le premier texte pris en application de cette réglementation a été signé le 25 janvier 2013. Il concerne à la fois l'éclairage intérieur émis vers l'extérieur des bâtiments non résidentiels (vitrines de commerces, bureaux…) et l'éclairage des façades de ces mêmes bâtiments et encadre les horaires de fonctionnement de ces installations. Une règle générale d'extinction est fixée, se déclinant de différentes manières selon le type d'application d'éclairage concerné :  
|  | • les éclairages intérieurs de locaux à usage professionnel doivent être éteints une heure après la fin d'occupation desdits locaux ;  
|  | • les éclairages des façades des bâtiments sont éteints au plus tard à 1h ;  
|  | • les éclairages des vitrines de magasins de commerce ou d'exposition sont éteints au plus tard à 1h ou une heure après la fin d'occupation desdits locaux si celle-ci intervient plus tardivement. Les règles qui encadrent l'horaire de rallumage de ces éclairages sont également spécifiées : |

276 Council of Europe Resolution 1776 (2010)
Tackling Light Pollution for Sustainability – An Approach for the Vesancy-Versoix Corridor

- les éclairages des vitrines de magasins de commerce ou d’exposition peuvent être allumés à partir de 7h ou une heure avant le début de l’activité si celle-ci s’exerce plus tôt ;
- les éclairages des façades des bâtiments ne peuvent être allumés avant le coucher du soleil.

En ce qui concerne les façades et les vitrines, le texte prévoit que les préfets peuvent déroger aux dispositions citées, en particulier, la veille des jours fériés chômés, durant les illuminations de Noël, lors d’événements exceptionnels à caractère local définis par arrêté préfectoral et dans les zones touristiques d’affluence exceptionnelle ou d’animation culturelle permanente.

**Art. L. 583-1 du code de l’environnement. Loi sur la biodiversité**


### 2009 - Art 41 loi Grenelle I

**Objectifs:** L’article 41 de la loi Grenelle 1 décline les 4 grands objectifs de la loi : « Les émissions de lumière artificielle de nature à présenter des dangers ou à causer un trouble excessif aux personnes, à la faune, à la flore ou aux écosystèmes, entraînant un gaspillage énergétique ou empêchant l’observation du ciel nocturne feront l’objet de mesures de prévention, de suppression ou de limitation. »

### 2010 - Art 173 loi Grenelle II

**Stratégie:** Définit l’architecture des textes, les sanctions, les autorités en charge du contrôle

### 2016 – Loi pour la reconquête de la biodiversité, de la nature et des paysages

Loi n° 2016-1087 du 8 août 2016

- **Art. L110-1 du Code de l’environnement modifié :** I. - Les espaces, ressources et milieux naturels terrestres et marins, les sites, les paysages diurnes et nocturnes, la qualité de l’air, les êtres vivants et la biodiversité font partie du **patrimoine commun** de la nation.
- **Art. L371-1 du Code de l’environnement modifié:** I-La trame verte et la trame bleue ont pour objectif d’enrayer la perte de biodiversité en participant à la préservation, à la gestion et à la remise en bon état des milieux nécessaires aux continuités écologiques, tout en prenant en compte les activités humaines, et notamment agricoles, en milieu rural ainsi que la gestion de la lumière artificielle la nuit.
- **5° de l’article L219-8 du Code de l’environnement modifié :** La " pollution " consiste en l’introduction directe ou indirecte, par suite de l’activité humaine, de déchets, de substances, ou d’énergie, y compris de sources sonores sous-marines ou de **sources lumineuses d’origine anthropique**, qui entraîne ou est susceptible d’entraîner des effets nuisibles pour les ressources vivantes et les écosystèmes marins, et notamment un appauvrissement de la biodiversité, des risques pour la santé humaine, des obstacles pour les activités maritimes, et notamment la pêche, le tourisme et les loisirs ainsi que les autres utilisations de

277 "Patrimoine commun" est associée à tous les paysages, voir : Loi n° 95-101 du 2 février 1995 relative au renforcement de la protection de l’environnement
### Tackling Light Pollution for Sustainability – An Approach for the Vesancy-Versoix Corridor

La mer, une altération de la qualité des eaux du point de vue de leur utilisation, et une réduction de la valeur d'agrément du milieu marin.

- **Art. L350-1 C. du Code de l'environnement créé**: Les objectifs de qualité paysagère mentionnés à l'article L. 333-1 visent également à **garantir la prévention des nuisances lumineuses** définie à l'article L. 583-1.
- **2ème alinéa de l'article L110-2 du Code de l'environnement**: Il est du devoir de chacun de veiller à la sauvegarde et de contribuer à la protection de l'environnement, *y compris nocturne*.

- **Règlement européenne 245/2009**: des restrictions de commercialisation des types de luminaires, par. ex. des boules à Mercure sont interdit à la vente depuis avril 2015.

<table>
<thead>
<tr>
<th>Année</th>
<th>Détails</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011 - Décret nuisances lumineuses</td>
<td>Décret n° 2011-831 du 12 juillet 2011 relatif à la prévention et à la limitation des nuisances lumineuses</td>
</tr>
<tr>
<td></td>
<td>Installations concernées ? Définition d’un zonage Encadrement du pouvoir d’interdiction ou de limitation “ponctuel” du Ministre</td>
</tr>
<tr>
<td>2012 – Décret enseignes et publicités</td>
<td>Décret n° 2012-118 du 30 janvier 2012 relatif à la publicité extérieure, aux enseignes et aux préenseignes</td>
</tr>
<tr>
<td></td>
<td>Règle générale d’extinction des enseignes et publicités lumineuses. Luminosité. Clignotements...</td>
</tr>
<tr>
<td>2013 - Arrêté extinction (vitrines, illuminations, bureaux)</td>
<td>Arrêté du 25 janvier 2013 relatif à l’éclairage nocturne des bâtiments non résidentiels afin de limiter les nuisances lumineuses et les consommations d’énergie</td>
</tr>
<tr>
<td></td>
<td>S'applique aux installations d'éclairage des bâtiments non résidentiels, recouvrant à la fois l'éclairage intérieur émis vers l'extérieur de ces bâtiments et l'illumination des façades de bâtiments, à l'exclusion des installations d'éclairage destinées à assurer la protection des biens lorsqu'elles sont asservies à des dispositifs de détection de mouvement ou d'intrusion.</td>
</tr>
<tr>
<td>Loi de transition énergétique pour la croissance verte 2015</td>
<td><strong>Art. 188</strong>: Dans le cadre des plans climat-air-énergie territoriaux, lorsque l’intercommunalité à l’origine de ce plan exerce la compétence en matière d’éclairage, le programme d’actions comporte un volet spécifique à la maîtrise de la consommation énergétique de l’éclairage public et de ses nuisances lumineuses.</td>
</tr>
<tr>
<td></td>
<td><strong>Art. 189</strong>: Les nouvelles installations d’éclairage public sous maîtrise d’ouvrage de l’Etat et de ses établissements publics et des collectivités territoriales font preuve d'exemplarité énergétique et environnementale conformément à l'article L. 583-1 du code de l'environnement.</td>
</tr>
<tr>
<td><strong>Nouvelles mesures de prévention de la pollution lumineuse, 2018</strong></td>
<td>Ministre Nicolas Hulot annonce le 13 octobre 2017 que de nouvelles mesures de prévention de la pollution lumineuse seront mises en place dans les mois à venir.</td>
</tr>
</tbody>
</table>
Tackling Light Pollution for Sustainability – An Approach for the Vesancy-Versoix Corridor

Ministère de la Transition écologique et solidaire

Le ministre de la Transition écologique et solidaire envisage notamment de mettre en place de nouveaux outils réglementaires pour aller vers plus de sobriété sur les sources d'éclairage non couvertes par la réglementation en vigueur, tels que les parcs de stationnement, les installations sportives, ou l'éclairage de mise en valeur. Il entend mobiliser l'ensemble des exploitants d'installations lumineuses afin de déterminer les outils les plus appropriés.

De même, il annonce que l’arrêté fixant la liste des sites astronomiques exceptionnels dans lesquels des mesures complémentaires seront mises en œuvre pour protéger le ciel et l'écosystème nocturnes sera publié au printemps.²⁷⁸

<table>
<thead>
<tr>
<th>Switzerland²⁷⁹,²⁸⁰,²⁸¹</th>
<th>Principles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Federal Act on the Protection of the Environment (EPA) - Loi sur la protection de l’environnement (LPE)</td>
<td></td>
</tr>
<tr>
<td>Art.1, al.2 : Les atteintes qui pourraient devenir nuisibles ou incommodantes seront réduites à titre préventif et assez tôt</td>
<td>Precaution</td>
</tr>
<tr>
<td>Art.11, al.1 : Les rayons sont limités par des mesures prises à la source</td>
<td></td>
</tr>
<tr>
<td>Art.11, al.2 : Il importe, à titre préventif, de limiter les émissions dans la mesure que permettent l’état de la technique et les conditions d’exploitation et pour autant que cela soit économiquement supportable</td>
<td></td>
</tr>
<tr>
<td>Art.7, al.7 : Toutes les installations fixes situées dans l’environnement qui produisent de la lumière artificielle ou modifient la lumière naturelle du soleil ; les appareils sont assimilés à des installations</td>
<td>Protection</td>
</tr>
<tr>
<td>Art.14 : Les valeurs limites d’immissions des pollutions atmosphériques sont fixées de manière que, selon l’état de la science et l’expérience, les immissions inférieures à ces valeurs : ne menacent pas les hommes, les animaux et les plantes, leurs biocénoses et leurs biotopes ; ne gênent pas de manière sensible la population dans son bien-être</td>
<td></td>
</tr>
<tr>
<td>Art.13 : Les seuils quantitatifs au-dessus desquels les immissions sont considérées comme excessives sont fixés par le Conseil fédéral sous la forme de valeurs limites d’immissions</td>
<td>Ceiling</td>
</tr>
<tr>
<td>&gt;&gt; pour la lumière, cela n’a pas encore été fait ; évaluation au cas par cas</td>
<td></td>
</tr>
<tr>
<td>Art.12 : Les émissions sont limitées par l’application : Des valeurs limites d’émissions ; des prescriptions en matière de construction ou d’équipement ; des prescriptions en matière de trafic ou d’exploitation</td>
<td>Emissions limitations</td>
</tr>
</tbody>
</table>

²⁷⁸ Collet, P. (2017)
²⁷⁹ Federal Office for the Environment (2017b)
²⁸¹ Debrot, L. (2016)
### Federal Act on the Protection of Nature and Cultural Heritage (NCHA) - Loi fédérale sur la protection de la nature et du paysage (LPN)

<table>
<thead>
<tr>
<th>Article</th>
<th>Text</th>
<th>Protection of biodiversity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Art.18, al. 1ter</td>
<td>Si, tous intérêts pris en compte, il est impossible d’éviter des atteintes d’ordre technique aux biotopes dignes de protection, l’auteur de l’atteinte doit veiller à prendre des mesures particulières pour en assurer la meilleure protection possible, la reconstitution ou, à défaut, le remplacement adéquat</td>
<td></td>
</tr>
<tr>
<td>Art.20</td>
<td>Possibilité d’interdiction de totale ou partiellement la cueillette, la déplantation, l’arrachage, le transport, la mise en vente, la vente, l’achat ou la destruction de plantes rares. Il peut également prendre des mesures adéquates pour protéger les espèces animales menacées ou dignes de protection.</td>
<td></td>
</tr>
<tr>
<td>Art.3</td>
<td>Prendre soin de ménager l’aspect caractéristique du paysage et des localités, les sites évocateurs du passé, les curiosités naturelles et les monuments historiques et, lorsque l’intérêt général prévaut, d’en préserver l’intégrité</td>
<td></td>
</tr>
<tr>
<td>Art. 6</td>
<td>Objet d’importance nationale dans un inventaire fédéral indique que l’objet mérite spécialement d’être conservé intact ou en tout cas d’être ménagé le plus possible, y compris au moyen de mesures de reconstitution ou de remplacement adéquates</td>
<td></td>
</tr>
</tbody>
</table>

### Ordinance on the Protection of Nature and Cultural Heritage (NCHO) - Ordonnance sur la protection de la nature et du paysage (OPN)

<table>
<thead>
<tr>
<th>Article</th>
<th>Text</th>
</tr>
</thead>
<tbody>
<tr>
<td>Art.14, al. 6</td>
<td>Une atteinte d’ordre technique qui peut entraîner la détérioration de biotopes dignes de protection ne peut être autorisée que si elle s’impose à l’endroit prévu et qu’elle correspond à un intérêt prépondérant</td>
</tr>
<tr>
<td>Art.14, al. 7</td>
<td>L’auteur ou le responsable d’une atteinte doit être tenu de prendre des mesures optimales pour assurer la protection, la reconstitution ou, à défaut, le remplacement adéquat du biotope</td>
</tr>
</tbody>
</table>

**>> lorsque l’atteinte est admissible, ces émissions doivent être limitées dans le cadre de mesures de protection**

### Federal Act on Hunting - Loi fédérale sur la chasse et la protection des mammifères et oiseaux sauvages (LChP)

<table>
<thead>
<tr>
<th>Article</th>
<th>Text</th>
</tr>
</thead>
<tbody>
<tr>
<td>Art. 7, al. 4</td>
<td>Conserver la diversité des espèces et celle des biotopes des mammifères et oiseaux indigènes et migrateurs vivant à l’état sauvage. Afin de préserver cette faune sur le long terme, il faut prendre des mesures permettant d’éviter que celle-ci soit dérangée</td>
</tr>
<tr>
<td>Art. 7, al. 4</td>
<td>Assurer une protection suffisante des mammifères et des oiseaux sauvages contre les dérangements</td>
</tr>
</tbody>
</table>

**>> dérangements causés par des émissions lumineuses liées aux activités touristiques, sportives ou autres dans les habitats des mammifères et oiseaux sauvages**

### Federal Act on Fishing - Loi fédérale sur la pêche (LFSP)

<table>
<thead>
<tr>
<th>Article</th>
<th>Text</th>
</tr>
</thead>
<tbody>
<tr>
<td>Art. 5</td>
<td>Désigne les espèces et les races de poissons et d’écrevisses qui sont menacées ; Prendre les mesures nécessaires afin de protéger les biotopes des espèces et des races menacées. Ils peuvent prendre d’autres mesures, en particulier interdire la pêche.</td>
</tr>
</tbody>
</table>

**>> aussi possible par rapport à la pollution lumineuse**

### Federal Act on Spatial Planning - Loi fédérale sur l’aménagement du territoire (LAT)

<table>
<thead>
<tr>
<th>Article</th>
<th>Text</th>
</tr>
</thead>
<tbody>
<tr>
<td>Art. 1, al. 2, let. a</td>
<td>Protection des bases naturelles de la vie, telles que le paysage</td>
</tr>
<tr>
<td>Art. 3, al. 2</td>
<td>Intégration des constructions et des installations dans le paysage ; conservation les sites naturels et les territoires servant au délassement</td>
</tr>
<tr>
<td>Art. 3, al. 3, let. b</td>
<td>Préserver autant que possible les lieux d’habitation des atteintes nuisibles ou incommodantes</td>
</tr>
<tr>
<td>Art. 3, al. 4, let. c</td>
<td>L’implantation des constructions et installations publiques ou d’intérêt public : d’éviter ou de maintenir dans leur ensemble à un minimum les effets défavorables qu’exercent de telles implantations sur le milieu naturel, la population et l’économie</td>
</tr>
<tr>
<td>Art. 17</td>
<td>Zones à protéger comprennent les cours d’eau, les lacs et leurs rives, de même que les biotopes des animaux et des plantes dignes de protection, les paysages d’une beauté particulière, d’un grand intérêt pour les sciences naturelles ou d’une grande valeur en tant qu’éléments du patrimoine culturel ;</td>
</tr>
</tbody>
</table>
Tackling Light Pollution for Sustainability – An Approach for the Vesancy-Versoix Corridor

les localités typiques, les lieux historiques, les monuments naturels ou culturels. Au lieu de délimiter des zones à protéger, le droit cantonal peut prescrire d’autres mesures adéquates.

Art. 24 : Certaines installations d’éclairage peuvent être autorisées avec des charges et conditions consistant en des mesures de protection contre les immissions lumineuses ; elles peuvent également être refusées.

>> Droit aux cantons de déterminer à sa manière quelle installation est soumise ou non à une autorisation

**Energy Act (EnA) - Loi sur l’énergie (LEne)**
Contribution à un approvisionnement énergétique suffisant, diversifié, sûr, économique et compatible avec les impératifs de la protection de l’environnement.

**Federal Road Traffic Act - Loi fédérale sur la circulation routière (LCR)**

Art. 32 : La vitesse doit toujours être adaptée aux circonstances, notamment (...) aux conditions de la route, de la circulation et de la visibilité

Art. 96 : Principes d’interdiction des réclames routières
Art. 98 : Réclames routières sur les autoroutes et les semi-autoroutes

**Swiss Civil Code (CC) - Code civil suisse (CC)**

Art. 679 : En cas d’excès du droit de propriété : Celui qui est atteint ou menacé d’un dommage parce qu’un propriétaire excède son droit, peut actionner ce propriétaire pour qu’il remette les choses en l’état ou prenne des mesures en vue d’écarter le danger, sans préjudice de tous dommages-intérêts

Art. 684 : Rapport de voisinage : Sont interdits en particulier la pollution de l’air, les mauvaises odeurs, le bruit, les vibrations, les rayonnements ou la privation de lumière ou d’ensoleillement qui ont un effet dommageable et qui excèdent les limites de la tolérance que se doivent les voisins d’après l’usage local, la situation et la nature des immeubles

>> La protection de droit privé contre les immissions

**Standards / Normes de droit privé**

Norme SIA 491 (SN 586 491) : Prévention des émissions inutiles de lumière à l’extérieur

>> Pas de valeurs indicatives pour l’appréciation des immissions excessives

Mesures/conditions générales :

Aires protégées : protection contre les émissions lumineuses ; Balance entre sécurité, intérêts publics et la prise en compte des effets négatifs ; Optimisation de la hauteur des lampes ; Éclairage du haut vers le bas ; Uniquement quand l’éclairage est nécessaire (entre 22h00 et 6h00 éclairage interdit pour les publicités, vitrines, décorations lumineuses…) ; Éviter les ondes courtes (UV et bleu) ; Éviter l’intrusion des petits organismes (insectes…) dans les lampes

Conditions spéciales : Bâtiments publics et privés, infrastructures de transport, objets naturels, installation pour les sports d’extérieurs et les loisirs, etc.

Norme de droit privé SN EN 12464-2 : 2007 « Lumière et éclairage -Eclairage des lieux de travail -Lieux de travail extérieur »

Norme de droit privé SN EN 12193 : 2008 « Lumière et éclairage - Eclairage des installations sportives »

•optimisation de l’éclairage des lieux de travail extérieurs et des stades
•chapitre sur les nuisances pour l’être humain et l’environnement
•valeurs indicatives pour l’appréciation de l’illumination de l’espace, de l’éblouissement désagréable et de la lumière orientée vers le haut
Tackling Light Pollution for Sustainability – An Approach for the Vesancy-Versoix Corridor

<table>
<thead>
<tr>
<th>Norme de droit privé CEN/TR 13201-1 et SN EN 13201-2 : Eclairage public (sélection des classes d’éclairage et exigences de performances)</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Tient compte des types d’usager : Nb de véhicules par jour et leur vitesse ; Présence de piétons ou cyclistes ; Zones de « conflits »</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Principal Judgments of the Federal Court - Arrêts principaux du Tribunal fédéral</th>
</tr>
</thead>
<tbody>
<tr>
<td>1997 : Éclairage du sommet du Pilate (NI), objet IFP no1605 (ATF 123 II 256)</td>
</tr>
<tr>
<td>2012 : Éblouissement par réflexion des rayons du soleil (ATF 1C_177/2011)</td>
</tr>
<tr>
<td>2013 : Éclairage de Noël à Möhlin AG (ATF 140 II 33)</td>
</tr>
<tr>
<td>2014 : Éclairage de la gare d’Oberrieden See ZH (ATF 140 II 214)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Federal Recommendations for the Prevention of Light Emissions - Recommandations fédérales pour la prévention des émissions lumineuses</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005 : Principe de limitation à la source ; Vérification des besoins ; Canalisation de la lumière ; Orientation correcte ; Sélection de l’intensité et de la qualité de la lumière ; Modulation de la durée d’éclairage</td>
</tr>
<tr>
<td>2018 : Actualisation des recommandations avec publication de la version définitive</td>
</tr>
<tr>
<td>« ...En 2013, le Conseil fédéral a mandaté l’OFEV d’actualiser et d’étendre ses « Recommandations pour la prévention des émissions lumineuses » de 2005 (voir communiqué de presse du 13.02.2013). Du 12 avril au 30 juin 2017, une consultation concernant le projet de l’aide à exécution actualisée a été effectuée... ».</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parliamentary initiative and monitoring activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009 : Postulat Moser - Emissions lumineuses et diversité des espèces</td>
</tr>
<tr>
<td>2017 : Programme «Observation du paysage suisse» documente et évalue l’évolution du paysage (34 indicateurs) -</td>
</tr>
<tr>
<td>« ...Entre 1994 et 1997, les émissions lumineuses ont augmenté de près de 40 % en Suisse. Elles sont ensuite restées relativement stables avec de légères variations jusqu’en 2007 avant de s’accroître à nouveau de façon marquée. La surface complètement obscure la nuit a également fortement diminué (de 30 % en 1994 à 20 % en 2012, valeurs applicables à toute la Suisse). Les grandes étendues naturellement obscures sont devenues rares, surtout sur le Plateau et dans le Jura. Cela entraîne une modification radicale de notre environnement naturel telle que la disparition du paysage nocturne. Il est donc important de réduire les émissions lumineuses pour retrouver une obscurité naturelle. L’une des mesures les plus efficaces consisterait à éteindre les éclairages publicitaires la nuit... »²⁸²</td>
</tr>
</tbody>
</table>

| Cantonal and Municipal Recommendations - Recommandations cantonales et communales |
| Ex. : Loi vaudoise sur les routes (LRou) et normes²⁸³ |
| Art. 21, al. 1 : L’éclairage est à la charge des communes |
| Art. 21, al. 2 : A titre exceptionnel, l’Etat peut prendre à sa charge tout ou partie de l’éclairage de tronçons de routes cantonales, notamment dans les tunnels et aux jonctions de routes importantes. |
| Art. 21, al. 3 : Les communes territoriales peuvent décider d’éclaire des tronçons de routes cantonales ; les plans d’éclairage doivent alors être soumis à l’approbation du département |
| VSS SN 640263 : Carrefours giratoires; Directive SLG 202 |
| SN EN 13201 ; SN EN 13201-1 ; SN EN 13202 à 13205 |

²⁸² Federal Office for the Environment (2016)  
²⁸³ Rolland, F. (2017)
## Tackling Light Pollution for Sustainability – An Approach for the Vesancy-Versoix Corridor

<table>
<thead>
<tr>
<th>Cantonal and Municipal Recommendations - Recommandations cantonales et communales</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ex. : Loi et règlementations genevois</strong>&lt;sup&gt;284&lt;/sup&gt;</td>
</tr>
<tr>
<td>Les éclairages et illuminations publics sont conçus, réalisés et exploités de manière à garantir une utilisation économe et rationnelle de l’énergie [...]</td>
</tr>
</tbody>
</table>

L'Etat et les communes établissent tous les 4 ans un diagnostic en matière d’efficacité énergétique et de pollution lumineuse de leur parc d'installations d'éclairages et d'illuminations publics.

- Sur cette base, l'Etat et les communes élaborent un plan directeur lumière, lequel décrit les mesures à prendre visant à concevoir, maintenir et exploiter lesdites installations de manière exemplaire en termes d'utilisation rationnelle de l'énergie et de diminution des émissions lumineuses polluantes.

---

<sup>284</sup> Spierer, E. (2017)
Tackling Light Pollution for Sustainability – An Approach for the Vesancy-Versoix Corridor

Annex 3 – Template questionnaire relating to the communes in the Vesancy-Versoix corridor contract (in France and Switzerland)

Nom de la commune : _________________________ Date: __________________________

Nom du répondant, titre, service: ________________________________________________

N.B. : Le questionnaire a été modifié par rapport à la commune et au moyen de communication.

2. Comme l’éclairage public est en corrélation, entre autres, avec l’urbanisation, la consommation électrique et la production de CO2, quelle est aujourd’hui la superficie de la commune affectée à la construction résidentielle, à la construction commerciale / industrielle, à l'agriculture et aux espaces naturels ? Comment cela a-t-il changé d’année en année au cours des 10 dernières années ? Quelle est la tendance jusqu’en 2030 et 2050 et au-delà?

<table>
<thead>
<tr>
<th>Commune</th>
<th>Aujourd’hui</th>
<th>Dernières 10 années</th>
<th>Tendance 2030</th>
<th>Tendance 2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total – Résidentielle – Commerciale/industrielle – Agriculture – Espaces naturels -</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3. Quelle est l'augmentation estimée prévue de la population dans la commune d’ici 2030 et 2050 ?


5. En ce qui concerne la construction future, existe-t-il des dispositions pour promouvoir ou suivre la réglementation des technologies de lumière intelligentes et écoénergétiques (si oui, lesquelles) ?

6. Quelle est la dernière carte orthophoto de nuit du corridor montrant les niveaux de pollution lumineuse ? Date indiquée ? Existe-t-il des cartes antérieures ?

7. Des mesures actuelles de la pollution lumineuse dans le Corridor au sein de la commune faisant partie du Grand Genève ont-elles été prises ? Quand cela a-t-il eu lieu et quel a été le résultat ? Existe-t-il des mesures antérieures ?

8. Est-ce qu'on a mesuré le niveau de biodiversité dans le Corridor au sein de la commune et/ou de la région ? Quand cela a-t-il eu lieu et quel a été le résultat ? Existe-t-il des mesures antérieures ? Des données montrent-elles la réduction de la biodiversité dans la commune, spécifiquement en lien avec les systèmes d'éclairage privé et public?

9. Quel est le nombre total de pôles lumineux installés en l’état actuel, répartis comme suit :

<table>
<thead>
<tr>
<th>Type de source</th>
<th>Région administrée [<em><strong><strong><strong><strong>] par partenaire [</strong></strong></strong></strong></em>] - point lumineux par type de source</th>
<th>Commune total pôles lampadaires en 2009</th>
<th>Commune - lieux / Emplacement</th>
<th>Commune total pôles lampadaires aujourd’hui</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Sodium haute pression</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. Sodium basse pression</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c. Vapeur de mercure</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>d. Fluo</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>e. Iodure Métallique</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>f. Halogénure de métal</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>g. Incandescence</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>h. LED en-dessous et jusqu’à 3,000 kelvin</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>i. LED de plus de 3,000 kelvin</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Tackling Light Pollution for Sustainability – An Approach for the Vesancy-Versoix Corridor

10. Est-ce que la commune a défini des zones et choisi des sources et modalités d’éclairage en fonction du trafic et de la fréquentation nocturne, par ex. de détection de présence, de réductions d’intensité, ou des zones pour éteindre l’éclairage à une certaine heure ? Dans quelles zones ?

11. Est-ce que la commune a défini des zones proches de zones naturelles (forêts, prairies, etc.) et agricoles où l’éclairage publique est à éviter ?

12. Pouvez-vous me donner un exemple de l’endroit où je peux voir ces éclairages qui réduisent leur intensité de 70% à 30% ? À quelle heure est-ce que la réduction de lumière est faite ?

13. Dans les zones piétonnes, les luminaires LED sont dotés de détection de présence : à partir de 22 h, le flux lumineux descend à 20% et remonte instantanément à 100% dès qu’une personne est détectée. Où est-ce qu’on trouve ces lumières qui réduisent leur intensité de 80% à 20% ?

14. Est-ce que toutes les lumières fonctionnent grâce au photovoltaïque ou seulement celles de XXX ?

15. Est-ce que c’est possible de changer l’angle des ampoules/lampes sur les lampadaires autour de xxx pour que la lumière soit dirigée vers le bas et pas vers les côtés (ce qui est éblouissant) ?

16. Est-ce qu’on peut changer les couleurs/spectres de ces ampoules blanches vers un spectre plus jaune (si LED 2.700 kelvin et pas 4.000 kelvin) ? Est-ce qu’on peut réduire l’intensité de ces lumières ? Est-ce qu’on peut éteindre ces lumières complètement à un certain moment de la nuit (et installer un détecteur de mouvement infrarouge pour que les animaux puissent passer, mais que les piétons et les actes de délinquance soient éclairés) ?

17. Quels ont été les investissements dans les systèmes d’éclairage public, année après année, au cours des 10 dernières années ?

18. Quel a été le coût de l’alimentation électrique utilisé pour les systèmes d’éclairage public, année après année, au cours des 10 dernières années ?

19. Quel a été le nombre d’accidents de la route, année après année, au cours des 10 dernières années, par type d’accident, en précisant les lieux, les dates et les heures du jour ou de la nuit ?

20. Quel a été le nombre d’accidents de la route impliquant la faune sauvage, année après année, au cours des 10 dernières années, en précisant les lieux, les dates et les heures du jour ou de la nuit ?

21. Je sais qu’il y a plus d’accidents, par exemple, pour la grande faune autour de Versoix, route de Sauverny entre la France et la Suisse. Y’a-t’il des données par rapport aux communes concernées que nous pouvons utiliser par rapport à la pollution lumineuse ?

22. Quel est le nombre d’incidents de criminalité déclarés, année après année, selon le type de crime - en précisant les lieux, les dates et les heures du jour ou de la nuit ?

23. Quels sont les accords internationaux relatifs aux systèmes d’éclairage public dans les communes de France / de Suisse ?

24. Quels sont les accords binationaux pertinents pour les systèmes d’éclairage public dans les communes de France / de Suisse ?

25. Quelles sont les lois, règlements, politiques et lignes directrices concernant l’éclairage et la pollution lumineuse en France / en Suisse ?
   a) Niveau national : _____________  b) Niveau régional : __________ c) Niveau communal : __________

26. Qui est responsable de la planification, du financement, de l’installation, de la gestion et de l’entretien des systèmes d’éclairage public pour la commune ?
   a) Planification : _____________  b) Financement : __________ c) Installation : __________
   d) Gérant : _____________  e) Entretien : __________

27. Comment l’éclairage public est-il contrôlé ? Est-ce que les lumières sont éteintes simultanément ou est-ce que cela se fait par secteur/quartier ? Comment la sélection est-elle faite ? Est-il possible d’éteindre des lampadaires individuellement ou uniquement de façon collective ?
En ce qui concerne la question des matériaux utilisés pour les systèmes d'éclairage actuels et futurs, comment est-ce que ces matériaux sont gérés par rapport à la chaîne d’approvisionnement (production, installation, réutilisation / recyclage / élimination écologiquement rationnelle des déchets) ?

Quels sont les budgets courants pour les systèmes d'éclairage (et aussi en pourcentage du budget total) pour la commune ?

a) Plan de placement annuel :

b) Les coûts d’exploitation :

i. Source d’électricité :

ii. Entretien :

iii. Autres coûts :

Est-ce que la commune peut, ou envisage de, générer de l’énergie nécessaire pour l’éclairage public avec des technologies renouvelables ?

La recherche sur internet indique que plus de XX % de l’énergie nécessaire pour l’éclairage public est générée par [source : ________________].

Si on utilise l’énergie renouvelable, est-ce que cela supportera le risque d’un effet rebond d’allumer plus et de ne pas essayer quand même d’éclairer plus modérément pour réduire la pollution lumineuse ?

Si la consommation de l’énergie est moins chère qu’avant grâce à l’introduction des nouvelles technologies comme les LED, est-ce que cela pourrait entraîner le risque d’un effet rebond d’éclairer plus et ne pas essayer quand même d’illuminer plus modérément dans les buts de réduire encore plus la consommation énergétique et la pollution lumineuse ?

Quels sont les fonds de l'UE utilisés pour les activités transfrontalières pour la pollution lumineuse ?

Quels sont les fonds français utilisés en France / Suisse ?

Quels sont les fonds suisses utilisés en France / Suisse ?

Quel est le nombre de plaintes concernant l’éclairage externe de nuit, à la fois en termes de lumière publique trop ou pas suffisante ou défectueuse ?

L’Office fédéral de l’environnement en Suisse est en train de mettre à jour ses recommandations d’aide d’exécution pour réduire la pollution lumineuse285. Est-ce que la commune a déjà considéré un éventuel plan d’application de ces recommandations ?

Est-ce que, à votre avis, les résidents de la commune sont-ils conscients des effets de la pollution lumineuse dans les domaines suivants ?

<table>
<thead>
<tr>
<th>Effets de la pollution lumineuse sur :</th>
<th>Commentaires</th>
</tr>
</thead>
<tbody>
<tr>
<td>La santé humaine</td>
<td></td>
</tr>
<tr>
<td>La faune</td>
<td></td>
</tr>
<tr>
<td>Les arbres et les plantes, les forêts</td>
<td></td>
</tr>
<tr>
<td>La productivité agricole (pollinisateurs, etc.)</td>
<td></td>
</tr>
<tr>
<td>Les écosystèmes aquatiques</td>
<td></td>
</tr>
<tr>
<td>La consommation énergétique / émissions du gaz à effet de serre</td>
<td></td>
</tr>
<tr>
<td>Le volume des déchets</td>
<td></td>
</tr>
</tbody>
</table>

38. Il existe plusieurs chartes sur la pollution lumineuse disponibles sur Internet, par ex. d’ANPCEN avec les communes et le syndicat d’énergie 286 ou Grenoble-Alpes-Métropole et FRAPNA 287, mais sans mentionner explicitement les spécifications technologiques. Lesquels des éléments de la charte seraient intéressants pour la commune ?

39. Est-ce qu’il existe une stratégie communale par rapport au développement durable dans les axes économique, social et environnemental ? Est-ce que la commune fait partie de la stratégie fédérale / nationale pour le développement durable, par exemple la stratégie 288 et des activités à niveau international comme par ex. la Convention des Maires 289 ou Comité 21 290 ?

40. Le développement durable concerne tout le monde. Quelles sont les actions envisagées par la commune pour sensibiliser et promouvoir les actions d’initiative citoyenne pour mener une vie plus durable, spécifiquement dans le cadre de l’éclairage/de la consommation énergétique/ de la protection de la biodiversité ?

41. Un des éléments du développement durable est la participation des citoyens. Comment est-ce que vous envisagez la participation des citoyens par rapport au planning et à la prise de décision au sujet de la transition énergétique liée à l’éclairage public ?

42. Pour co-développer des solutions d’amélioration de l’éclairage public, d’échanges des expériences, de l’expertise, des ressources, etc., est-ce que vous pourriez imaginer quelles modalités seraient les plus efficaces en vue d’une éventuelle collaboration entre XXX et une commune en Suisse ?

Merci beaucoup pour votre temps et vos précieuses réponses.

---


Tackling Light Pollution for Sustainability – An Approach for the Vesancy- Versoix Corridor

Annex 4 – Nocturnal orthophotos

Orthophoto showing various types of lighting in one of the communes

Accessible via SITG, URL: https://www.etat.ge.ch/geopartail/pro/?share=1a562a3e-4ac5-4735-b11c-4ad914600c33

Source: SITG, 14.04.2013
**Annex 5 – DPSIR Assessment Framework**

The DPSIR Assessment Framework components are interrelated in causal chains as the **Driving forces** (i.e. needs, causes or activities), **Pressures** (i.e. the results in meeting these needs, which become a burden to the environment), **States of the environment** (combining the quality of same and its physical, chemical and biological conditions of the environmental compartments of e.g., ecosystems, health, air, water, soil, etc.). Due to the interdependence of various variables, changes in the environment often have an **Impact** on ecosystems and their life-supporting functions. Finally, the cause-effect relationships have an impact on the socio-economic performance of a society. Responses refer to the measures of correction by society or policy makers to one or all of the aforementioned elements of the framework. The DPSIR Framework allows to assess causes and impacts of light pollution in the Vesancy-Versoix corridor, focusing particularly on biodiversity, and identify appropriate policy responses. This will involve assessing current policies and measures and the possible need to upgrade these to meet the challenge.

---

**DPSIR Framework**

|-------------------------------------|---------------|---------------|-------------------------|----------------------------|--------------------------|-----------------------------------|------------------------|--------------------------------------|
| Demographic growth, need for habitat | Poor quality of night / view of night sky | Continued exposure to outside light throughout the night, often even within the home | Increasingly all-night, pervasive and intensive outside light emissions in both urban and rural areas | Consciously, substantial light pollution as reflected in sky glow, glare and light trespassing | Continued exposure to artificial light throughout night | Substantial continued exposure to artificial light throughout the light | Light penetration into bio corridors, wildlife resting / feeding areas, forests, etc. | Public awareness / education & information aimed at specific target groups (e.g. citizens, government officials, schools, farmers, hunters, NGOs, etc.) on the effects of light pollution, rate of biodiversity loss & related ecosystem service performance and the need to protect biodiversity – including paradigm shift | Physical, mental, spiritual, health & quality of life negatively affected by light pollution due to:
  - Sleep deprivation and hormonal changes resulting in depression, mental illness, cardiovascular disease, cancer,
  - Difficulty in accessing the green, healthy, spiritual benefits of enjoying the beauty of the night sky and a deeper contact with nature (wildlife, see birds)
  - Limited opportunities for night-time, nature-related recreational activities (e.g. astronomy, night-walking, bird-watching, nature hikes, etc.), i.e. loss of recreational value for locals, tourism
  - Road stress / accidents caused by blinding light glare from other vehicles
  - Human injuries / deaths from accidents at animal road crossings due to disturbances of their natural day / night cycles
  - Substantial light causing disruptions in the movements of wild animals for purposes of feeding, rest and reproduction, significantly affecting species & genetic biodiversity
  - Animal injuries and deaths from accidents at dark animal road crossings due to speeding vehicles
  - Increase in resilience and loss of ecosystems & their services & increase in non-indigenous invasive species

---

**Drivers**
- Changes in land use – growing urbanization, encroachment upon agricultural and natural areas
- Increase in building infrastructure – residential, commercial, industrial, administrative, light poles
- Increase in traffic circulation of vehicles & longer work commuting
- Increase in energy & light consumption
- Overexploitation of natural resources

**Public sector policies and investments**
- Increase in investment needs (public lighting & buildings) & modernization
- Priority to savings (e.g. in energy consumption)

**Psychological**
- Today’s cultural fear of darkness
- Perception that extensive public lighting equals modernity and security
- Lack of awareness of the relative impacts of excessive light at night (on physical & mental health, diminished quality of life, biodiversity, etc.)
- General concern for health-related issues
- Need for rest, relaxation and recreation
- Deep-seated utilitarian need for access to nature and to the night sky view

**Technological**
- Lighting technology evolving towards low-energy, brighter/white lighting

---

**Responses**
- Policy, legal & regulatory frameworks
- Stringent zoning regulations to protect natural areas
- Intensive regulations on nighttime traffic in sensitive wildlife (migration) areas
- Technical regulations on the application of lighting technologies
- Indicators for informed environmental & socio-economic assessments and cost-benefit analysis
- Management of demand & supply of ‘green’ energy and lighting technologies

---

**291 European Environment Agency (n.d.)**

---

**Kristensen, P. (2004)***
Tackling Light Pollution for Sustainability – An Approach for the Vesancy-Versoix Corridor

Annex 6 – Draft letter for survey for residents on light pollution and its effects
Available in English and French

Grand Genève region, September 2017

Dear resident of the Greater Geneva area,

My name is Kerstin Ludwig and I am currently working on a research project about light pollution, energy transition and biodiversity at the University of Geneva, Switzerland. This research is intended to reflect the views of people within the Vesancy-Versoix biological corridor (covering parts of the Pays de Gex, and the cantons of Vaud and Geneva), which includes your commune. Your help and assistance in completing the questionnaire at the following web link will be invaluable for the study.

(WEB LINK ADDRESS HERE) – English
(WEB LINK ADDRESS HERE) - French

All the information you provide will be completely anonymous and confidential.

The questionnaire asks for your responses concerning environmental issues that may affect you and about how you feel about light and the dark, security and safety, light pollution and its effects on humans and on biodiversity, and what can be done to reduce it. If you don’t want to answer all the questions, you do not have to. Please just do what you can. It should take ten minutes to complete, and I hope you will enjoy it.

At the end of the project, key findings from the survey will be provided to the University of Geneva and to other interested organizations. If you wish to see the survey results yourself, I would be happy to provide these. For this, kindly include your email address at the end of the questionnaire. Should you have any queries or concerns about the survey, please contact me at the email address below.

Thank you very much for your kind help.

Yours faithfully,

Kerstin Ludwig
Student, Certificate of Advanced Studies in Sustainable Development, University of Geneva
Email: pollumgg[at]gmail[dot]com
Annex 7 – Draft survey for residents on light pollution and its effects

N.B.: Survey to be modified to fit max. 10 min of duration. Available in English and French

OUR ENVIRONMENT
1. How important do you believe are the following environmental issues for the Grand Genève region?
   Very important (VI), Important (I), Somewhat important (SI), Not important (NI), Don’t know (DK)
   a. Emissions of greenhouse gases
   b. Air pollution
   c. Light pollution
   d. Contamination of rivers and lakes from agricultural runoffs and other pollutants
   e. Rapid growth of urban areas leading to disappearance and fragmentation of natural areas
   f. Loss of biodiversity, i.e., the disappearance of local animals and plants
   g. Introduction of dangerous synthetic substances into the environment
   h. Waste of materials and energy

2. How much do you agree with the following statements?
   Agree fully (AF), Agree partly (AP), Disagree partly (DP), Disagree fully (DF), Don’t care (DC)
   a. I feel comfortable in the dark
   b. I love to look up into the night sky
   c. We need to be close to nature to be happy
   d. Since most animals are nocturnal, they should be able to move about in the dark unhindered
   e. Biodiversity is crucial for human health, food security and economic development
   f. It is important to protect wild animals and plants, as large numbers are threatened with extinction
   g. Small steps taken in our daily lives can impact upon the environment and on biodiversity

OUTSIDE LIGHTING
3. Which of the following purposes of outside lighting at night are important to you?
   Very important (VI), Important (I), Somewhat important (SI), Not important (NI), Don’t care (NC)
   a. Being able to find my way around
   b. Feeling more secure against crime
   c. Contributing to safety against traffic accidents
   d. Being able to view commercial advertisements and shop displays
   e. Making my commune look attractive and feel welcoming
   f. Enabling me to enjoy outdoors activities at night

SECURITY AND SAFETY
4. Which of the following are the best light-related ways to prevent crime (e.g. theft, burglary and physical violence)?
   Very important (VI), Important (I), Somewhat important (SI), Not important (NI), Don’t know (DK)
   a. Lights turning on and off within and outside the home with timers and/or movement detectors
   b. Bright street lighting kept on all night
   c. Dimmed street lighting that brightens to full strength when there is movement due to human activity
   d. Dimmed street lighting that is turned off late at night (e.g. 23h00-06h00), and adapts in real-time to movement and weather conditions

5. Which are the best ways to avoid traffic accidents at night through street lighting?
   Very important (VI), Important (I), Somewhat important (SI), Not important (NI), Don’t know (DK)
   a. Street lights kept on everywhere, all night
   b. Street lights on the main roads, with dimmed lights on side streets, all night
   c. Street lights turned on only during the main traffic hours, and dimmed late at night (e.g. 23h00-06h00)
   d. Street lights turned on only during the main traffic hours, and turned off entirely late at night
e. Street lights turned off late at night, but turned on again whenever there is movement of vehicles or people on the streets

LIGHT POLLUTION AT NIGHT

Light pollution is created when light is excessive or unnecessary. It can expand for hundreds of kilometres even affecting areas that in daytime would seem to be untouched by human presence. There are different kinds of light pollution, for instance: artificial sky glow reaching high and far above urban areas; light glare that blinds you; cluttered lights that shine too brightly; and light that trespasses into your home from outside. In effect, 99% of Europe’s population lives under light-polluted skies. In Switzerland, light pollution has increased by 70% since the 1990s and is expected to double in the coming years due to the increased use of LEDs. Light pollution has many negative consequences on human health and wellbeing. It also harms wildlife feeding, movement, reproduction and rest. Plant growth cycles are also much affected, as are many micro-organisms at the bottom of the food chain.

6. How important to you are the following problems associated with light pollution?
Very important (VI), Important (I), Somewhat important (SI), Not important (NI), Don’t care (DC)
   a. It wastes energy and money
   b. It disturbs wild animals and plants, contributing to loss of biodiversity
   c. Inability to enjoy the night sky
   d. It comes into people’s homes and disturbs their sleep cycles, which may lead to serious health issues
   e. It can make it easier for criminals to observe potential victims and to identify items to be stolen
   f. It can blind people when driving or when they need to see what is beyond the lights

7. How much have you felt bothered by the following effects of light pollution?
Very much (VM), Much (M), A bit (AB), Not at all (NA), Don’t care DC)
   a. Being distracted by illuminated advertisements
   b. Artificial light keeping away wild animals
   c. Light shining up vertically or horizontally to illuminate monuments, buildings or trees
   d. Brightly lit sport facilities, when nobody is around
   e. Traffic accidents involving wildlife in dark areas where animals need to cross due to landscape fragmentation and excessive light elsewhere
   f. Excessive and/or white (instead of using a warm, e.g. yellow/orange) lighting making my neighbourhood less cosy

8. How important is it to you to have more and brighter street lights even though these lights will have a negative effect on wildlife and plants?
Very important (VI), Important (I), Somewhat important (SI), Not important (NI), Don’t care (DC)

9. Do you believe that we have an ethical duty to live our lives such that our present needs are met without compromising the ability of future generations to meet their own needs?
   a. Agree fully (AF) _______; why? _____________________________________________________________
   b. Do not agree (DN) ______ why not? _________________________________________________________
   c. Don’t care (DC) ______ why not? __________________________________________________________

REDUCING LIGHT POLLUTION

10. Which do you believe are the most important ways to reduce light pollution? (VI, I, SI, NI, DK)
   a. Creating greater awareness in the population and getting them involved
   b. Setting stricter regulations or guidelines on public and commercial lighting systems
   c. Setting stricter regulations for residents on any light pollution that they create
   d. Developing or implementing lighting technologies that reduce or eliminate light pollution
   e. Raising the price of electricity to make consumers pay more for any light pollution that they create

---

Tackling Light Pollution for Sustainability – An Approach for the Vesancy-Versoix Corridor

11. Which are the most important ways for communes to ensure the participation of residents in reducing light pollution? (Very important (VI), Important (I), Somewhat important (SI), Not important (NI), Don’t care (NC))
   a. By organising public consultation events
   b. By creating neighbourhood workshops to find solutions to local light pollution issues
   c. By inviting comments on local lighting plans and designs at your commune’s city hall and on its website
   d. By organizing light-reducing awareness events, e.g. storytelling, pilot light shut-off projects, exhibitions, etc.
   e. Other(s):

12. Do you know of any communes in the region that have acted to reduce light pollution?
   a. No
   b. Yes, but I don’t know in which ones
   c. Yes, I do; these are the communes: __________________________

13. Please write down below any additional comments you may have on light pollution and on how you think it can be reduced:

GENERAL INFORMATION

To be able to better understand and compare the views of different groups of people, the following information is helpful to the research:

14. Your gender is:
   a. ___ Female
   b. ___ Male
   c. ___ Prefer not to say

15. Your age group (in years) is:
   a. ___ Under 15
   b. ___ 16 – 24
   c. ___ 25 – 35
   d. ___ 36 – 50
   e. ___ 51 – 62
   f. ___ 63 – 70
   g. ___ 71 or older
   h. ___ Prefer not to say

16. Please indicate the commune in which you live within the Greater Geneva region:
   a. Département de l’Ain: ____________________________ (name of commune)
   b. Département de Haute-Savoie: __________________ (name of commune)
   c. Canton Vaud: ________________________________ (name of commune)
   d. Canton Genève: _________________________________ (name of commune)
   e. Other: ________________________________ (name of commune)

17. In which type of neighborhood do you live:
   a. ___ In the town center
   b. ___ In a semi-rural area
   c. ___ In a rural area
   d. ___ Other: ______________________________

18. In which type of housing do you currently live in:
   a. ___ A house with an outside garden or terrace
   b. ___ A house without an outside garden or terrace
   c. ___ An apartment with a balcony allowing me to look up into the night sky
   d. ___ An apartment without a balcony
   e. ___ Prefer not to answer
   f. ___ Other: _______________________________
19. How long have you lived in the Greater Geneva area?
   a. Under 1 year
   b. 1 -3 years
   c. 4-10 years
   d. More than 10 years
   e. Prefer not to answer

20. Which types of outdoor recreational activity do you enjoy most? (Select as many as may apply)
   a. ___Walking / strolling / jogging
   b. ___Hunting
   c. ___Fishing
   d. ___Gardening
   e. ___Star gazing / astronomy
   f. ___Bird watching / observing animals
   g. ___Other: __________________________________________________________________

21. If you would like to receive a copy of the results of this research, please enter your email address here:
    ____________________________________________________________ (Optional).

Thank you very much for your time and for your responses. If you would like to obtain further information on light pollution, you may consult the internet or feel free to contact me.
Résumé de la Représentation : (Please see in English below)

C’est l’histoire d’une famille, Monsieur et Madame Rideaux, leur fille, Tanya, et leur fils, Thomas. Ils habitent le village d’Illuminia, dans une petite maison proche de la forêt. À côté de cette maison clapote un petit lac et pousse un grand arbre. Derrière chez eux, le chemin et ses trois lampadaires posent problème à toute la famille, mais aussi à la faune alentour. Notre bel arbre aussi a des soucis… Un voleur apparaît même dans notre histoire ! Finalement, le problème est résolu grâce à tout le monde travaillant ensemble, et avec l’aide de Madame le Maire du village.

Cette petite comédie musicale (environ une demi-heure) – avec de courtes chansons composées spécialement à cet effet – sera jouée et chantée par des enfants, appuyés par le chœur et le piano. Nous aurons aussi (options encore à définir) de belles chansons bien connues chantées par le chœur et par des solistes accompagnées d’un piano, et encore une pièce musicale à la harpe. Quelques récitations poétiques ponctuent l’ensemble.

L’histoire nous rappelle la beauté de la nuit… et la nécessité d’utiliser notre lumière sagement pas seulement pour économiser notre énergie mais aussi – très important – pour protéger notre santé et celle de la faune et de la flore qui nous entourent.

Résumé of the Performance: (performed in French)

This is the story of a family, Monsieur and Madame Rideaux, their daughter, Tanya, and their son, Thomas. They live in a small house, nearby the forest, in a little village: Illuminia. Next to the house is a small lake and a large, beautiful tree. Behind the house: the road, with three lamp-lights that turn out to be a problem not only for the family, but also for wildlife, large and small, and even for our tree. A thief also appears in our story. Finally, the problem is resolved by everyone working together, with the help of Madame le Maire of the village.

Our brief musical play (about half an hour) – with short songs composed specifically for this occasion – is acted and sung by children supported by the choir and piano. We will also have (options yet to be decided) some beautiful well-known songs sung by the choir and by soloists accompanied by the piano, and a musical piece performed on the harp. Some poetry recitals complete the ensemble.

Our story reminds us of the beauty of the night… and the need to use our light wisely not only to save energy but most importantly to also protect our health and the health of the wildlife and plants that surround us.
Tackling Light Pollution for Sustainability – An Approach for the Vesancy-Versoix Corridor

Flyer "La beauté de la nuit", February 2018

Découvrez la comédie musicale du Léman

LA BEAUTÉ DE LA NUIT

Entièrement réalisée et jouée par un ensemble amateur (*)
dont les enfants de l’Ecole de Challex

La famille Rideaux habite le village d’illumina, près
de la forêt. La vie est douce, mais des menaces pèsent
sournoisement sur les êtres vivants de cette île ...

Samedi 07 Avril 2018, 19h30
Challex (Salle Jean-Antoine Lépine)

Mercredi 02 Mai 2018, 17h00
Thoiry (Salle des fêtes)

Samedi 12 Mai 2018, 20h30
Fort l’Écluse (1)

(*) Chœur bénévole dédié, Harpiste, Pianiste et d’autres instrumentalistes

La Beauté de la Nuit

Une comédie musicale entièrement créée,
produite et jouée par des troubadours et
musiciens amateurs.

Une démarche de citoyens lémaniques de toute nationalité,
engagés pour le respect de la nuit, de la nature et de la santé.

L’histoire de la famille Rideaux est l’occasion de montrer avec
humour et poésie l’impact des lumières artificielles sur notre
quotidien, organisme et écosystème.

Apprendre de simples gestes et de nouvelles habitudes pour savourer
intelligemment notre jour et notre nuit.

PROGRAMME DE VOTRE SOIRÉE

Accueil
Spectacle
Exposition

ENTRÉE LIBRE

Petite Restauration organisée par le Sou des Ecoles de Challex

(1) prévoir des vêtements chauds
Informations : pollumgg@gmail.com
Acknowledgements

I wish to thank Professor Dr. Jörg Balsiger, Program Director for the Certificate of Advanced Studies (CAS) in Post-2015 Sustainable Development for his very valuable and rapid expert advice. My thanks go also to my external referent, Mr. Vincent Scattolin, Deputy Mayor in charge of urban planning at the Municipality of Divonne les Bains for his useful information and support. For providing useful information on the communes, I wish to thank Mr. Daniel Masson, Directeur des services techniques (Divonne les Bains) and for Mies, I wish to thank both Mr. Guy Deriaz, Vice-Syndic and Municipal des travaux, des routes et des espaces verts, Mr. Claude Hilfiker, Municipal des infrastructures, des services et de l’environnement, and Mr. Jerome Bastian of Duvoisin-Groux. For their guidance and useful discussions, I wish to thank the Département de l’environnement des transports et de l’agriculture (DETA) of République et canton de Genève, in particular Mr. Bertrand von Arx, Directeur de la biodiversité, Ms. Aline Blaser, Responsable du programme corridors biologiques and Ms. Joëlle Massy, Responsable système d’information géo référencé. Furthermore, due thanks go to Mr. Henrich Duriaux, Département de l’aménagement, du logement et de l’énergie (DALE) for facilitating quick access to nocturnal orthophotos. I also wish to thank Ms. Tali Nyffeler-Sadras, Chargée de projets Environnement at the Conseil régional du district de Nyon, Ms. Cécile Georget, Responsable gestion des milieux naturels at the Community of Municipalities of the Pays de Gex, as well as Mrs. Lucile Hanouz and Ms. Sophie Ginter from the Fédération Rhône-Alpes de protection de la nature (FRPANA) de l’Ain for their time and helpful information. Moreover, thanks go to the staff at the Municipality of Divonne les Bains, to local associations, the participants at the trans-border workshop on reducing light pollution organized by the Swiss local authorities and FRAPNA, and also the unknown interviewees picked for my field research for their time and patience. I am extremely grateful for Mr. Robert Smith-Gillespie’s valuable discussions, support and editing for the research project and his ongoing collaboration in our creative sensitization measures for the Greater Geneva region. During and after the CAS, my study peer Ms. Sabine Goel and I benefited from rich exchanges since we both covered the topic of light pollution and sustainability - one set in the Francophone trans-border Greater Geneva area and the other in Switzerland’s German-speaking Canton of Aargau. We both appreciated the comments received from our CAS lecturers and peers throughout the study programme, which provided insights from an academic, professional and stakeholders’ perspective. My thanks are also extended to Mr. Javier Teran Castro’s useful comments on the draft survey, to Mr. John Myers for some professional editing in English, and to Ms. Sophie Ginter and Mrs. Anne Derobert for making sure that the French displayed in the annexes was flawless.

The author declares no conflict of interest and that no funding was received for this study.
Bibliographical References


Tackling Light Pollution for Sustainability – An Approach for the Vesancy-Versoix Corridor


Tackling Light Pollution for Sustainability – An Approach for the Vesancy-Verboix Corridor


Tackling Light Pollution for Sustainability – An Approach for the Vesancy-Versoix Corridor


Tackling Light Pollution for Sustainability – An Approach for the Vesancy- Versoix Corridor


Freeman, S. (2015). Want to be more selfless? Try gazing at the stars: Feeling a sensation of awe from the world around us could make us kinder. Daily Mail, 21.05.2015. URL: http://www.dailymail.co.uk/news/article-3090259/Gazing-stars-make-kinder.html#ixzz4xDdT86CW, accessed 01.11.2017


Tackling Light Pollution for Sustainability – An Approach for the Vesancy-Versoix Corridor


Tackling Light Pollution for Sustainability – An Approach for the Vesancy-Versoix Corridor


Knop, E. et al. (2017). Artificial light at night as a new threat to pollination, Nature 548, 206-209, 02.08.2017, DOI 10.1038/nature23288, accessed 06.08.2017


Tackling Light Pollution for Sustainability – An Approach for the Vesancy-Versoix Corridor


Natural Step (n.d.). The four system conditions of a sustainable society. Ottawa, ON, Canada. URL: http://www.naturalstep.ca/four-system-conditions, accessed 08.02.2017
Tackling Light Pollution for Sustainability – An Approach for the Vesancy-Versoix Corridor


Tackling Light Pollution for Sustainability – An Approach for the Vesancy-Versoix Corridor


Reichel, A. (2017). *Degrowth as growth independence – Interview with Uwe Schneidewind* [Degrowth@AoM Blog post], accessed 12.11.2017


Tackling Light Pollution for Sustainability – An Approach for the Vesancy-Versoix Corridor


Tackling Light Pollution for Sustainability – An Approach for the Vesancy-Versoix Corridor

Shang, Y. et al. (2014). White light-emitting diodes (LEDs) at domestic lighting levels and retinal injury in a rat model. *Environmental Health Perspectives* 122:269-276; URL: http://dx.doi.org/10.1289/ehp.1307294, accessed 09.10.2017


Swanson, B. (2012). *Creating a shared vision: strategies and techniques to inspire teams*. agile42, Presentation 02.08.2012, URL: https://www.slideshare.net/dleyanlin/shared-vision-14644934, accessed 06.03.2017


Tackling Light Pollution for Sustainability – An Approach for the Vesancy-Versoix Corridor


University of Hong Kong (2014). HKU engages the community and students in light pollution awareness via light pollution workshops and competitions, 29.05.2014. URL: http://www.hku.hk/press/press-releases/detail/11253.html, accessed 05.05.2017


Tackling Light Pollution for Sustainability – An Approach for the Vesancy-Versoix Corridor


