Sustainable lighting products for all

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Abstract

Energy and lighting are crucial to human well-being and to a country's socio–economical and health-environmental development. Despite of this, over ¼ of the world is without access to electricity and the 25% of the world is using fuel-based lighting, paying more for less light performance. An increasing global trend of going off-grid for energy and lighting provision is shown both in developing and developed countries: this aims to a global more sustainable use of energy, more inclusive lighting performance and a general more meaningful way of living. The analytical phase of this paper presents a series of examples and scenario showing how the design contribution can influence the development of the lighting for all from the technological point of view but also focusing more on social factors such as the consumer education: design is taking an active part in the change towards new models concerned with environmental issues and energy savings.

KEYWORDS: lighting sustainability for all, solar lighting products, energy efficiency, off grid lighting solutions, sustainable lighting systems

Introduction

Energy is crucial to human well-being and to the socio-economical and health-environmental development of a country; conversely the situation of energy access is far for being a right for all: more than two billion people worldwide have no electric power and no hope of connecting on a national utility grid and an additional billion people have access for less than five hours a day. This data shows that over ¼ of the world is without access to electricity, including not only emergent countries but also underdeveloped or remote areas in the United States (IEA, 2010).

Among several deficiencies, energy lack is the cause of poor access to good-quality lighting: the 25% of the world obtains lighting from flame-based sources enjoying less than 0.01% of the illumination and paying more money in respect to people in the electrified world. The kerosene-based lighting obtains less than a thousandth of the illumination per unit of money as do those in industrialized countries. The condition of energy and lighting poverty is based

on the fact that the poorest of the poor pay far more than the rich, for each unit of illumination, living mostly in darkness condition if compared with the light levels of the most developed countries. The kerosene lanterns provide few lux only in few rooms of the house with an inadequate illumination, while, on the other side, western society use from 100 to 10,000lux depending on the activity, over-lighting the cities, the shopping centers and also private houses. (Mills, 2000; Mills. & Jacobson, 2011) This unbalanced situation should be redefined with new "ecologies" or sustainable lighting systems that take into account not only the use of more efficient technologies, such as off-grid, LED-based, adaptive, intelligent and more cost effective systems, but also rethink the social behaviour toward the responsible use of lighting and energy.

Re-Lighting "developing countries"

New countries are striving to improve their quality of life: several surveys shows that people rank lighting at the highest point among a set of improvements desired for their houses and affirm that they would acquire an additional lamp for their house if they could afford it within the fuel. What would happen if every person and community across the globe had access to free energy and good lighting? What would happen to the social and economic make up of their towns and cities? In order to change the situation in this direction, a series of worldwide movements are acting for ensuring the universal access to energy by 2030. In particular, energy can provide proper lighting, the key element of successful, industrious communities: it is useful for new income generation opportunities for small businesses, longer and better illumination for studying, extending productive hours in the home as well as reducing indoor air pollution (Mills. & Jacobson, 2011).

The energy access is supported by valuable and innovative investment, abandoning the traditional notion of centralized macro-grid energy schemes and focusing on the micro-scale based on renewable sources of energy that are the best and most cost-effective options for providing a universal access to energy: solar mini-grids, solar home systems (SHS) and solar portable lighting (SPL) products. These new sustainable lighting systems are available thanks to technical advances of both lighting sources (LEDs), batteries and solar photovoltaic systems (Alstone, Mills & Jacobson, 2011). In addition to this, a qualitative design approach has generated a series of more performing products, focused on the consumer needs, activities and demands: these new upgraded solutions need innovative and more affordable commercial systems and a stronger education of the communities for a responsible use.

Re-ducing the light of "developed countries"

What if developed societies would de-growth their lifestyle, changing for a more simple and energetically responsible attitude? What would happen to their town and cities? How should be designed then? An interesting approach is depicted by the de-growth scenario of Latouche (2008) and by the idea of energy democratization of Rifkin (2011) that are describing new living ways for the so called " developed countries" in order to face the energy, pollution and food crisis that are expected in the next decades. These scenarios are based upon a different logic: a more sober living, consuming less but better, producing less waste and recycling more, collecting cleaned energies and sharing it with others such as communication and information in a sort of collective community. The suggestion is to

regain a sense of proportion and a sustainable ecological footprint, establishing new social interactions and a new way to share resources.

Lighting efficiency is today a very important issue that is generally associated to the highest quantity of lighting achieved within the lowest consumed energy through new efficient and smart technologies. On the other hand the quality of light is far more important than the quantity of light (Peters, 1992) and the rediscovery of darkness is as important as lighting itself for the human comfort and well-being (Tillet, 2011; Tanizaki, 1982). More than this, there is a persuasive evidence that lighting efficiency cannot be solved just by replacing lighting systems with more efficient technologies: this will instead generate more consumption and energy demand (Owen, 2010). Both in emerging countries and above all in developed societies, efficiency and technology alone are not the answer. The design of efficient lighting products should be accompanied by educative tools for the meaningful ways of using it.

The research question

The background statement is that there is a worldwide unbalanced use and access to light and there is a huge understanding that, while developing countries needs to increase their quality of life starting from the very basic lighting rights, developed ones has to rethink their lifestyles, resizing their consumes in a more responsible and sustainable way. The question is how design is enabling people across the globe to access free energy and good lighting? What kind of solutions is design building toward this lighting for all achievements? Are they slow and fragmented solutions or are they following a common big ideal? How design is affecting positively the change toward the lighting for all scenario? This paper perhaps is not completely answering all this questions, but it is starting to investigate the problem of lighting quality for all presenting thoughtful best practice and shared theories toward this lighting for all idea. The hypothesis is that there are positive examples of design that are currently driving, from different points of view, the inclusive lighting sustainability.

Re-Design off-grid solar lighting devices (SLD)

Low-costs and energy efficiency are providing new opportunities for designing simple, small and cheap devices in order to assure energy and light, connecting remote and underserved countries, towns and villages to a self-efficient autonomous grid. Off-grid SLD, especially designed for emerging countries, are focused on users and present an inner multi-quality capacity: this is relative to intended use, to material quality and physical functionality.

First of all, efficient performance is the main critical issue: lighting output, run times and solar charging rates are directly dependant on the efficiency of the energy collection system and the energy use of lighting systems. Due to the higher performance and lower prices of LEDs, photovoltaic cells and batteries, SLD have gained a longer life and provide better illumination. About the performances, the Lighting Research Center in New York has been testing different types of SLD as well as The Lumina Project, an initiative of the U.S. Department of Energy's Lawrence Berkeley National Laboratory and also Lighting Africa that has developed a Standardized Specification Sheet for Off-Grid Lighting Products that includes information about product features, performance and lifetime. This guide offer a trusted resource for performance and quality verification for distributors and aims to offer to

the end-users an educative tool in order to distinguish between quality and substandard solar lamps.

Design has influenced also the distribution and servicing system: SLD are sold in a different way, removing the taxis and tariff burden and allowing consumers to purchase smaller and cheaper units of light over time through modular systems or through "pay per use" delivery models. In fact, the main obstacle to making the switch to clean, off-grid solar lighting is the up-front cost of solar portable lanterns: Kerosene may be expensive, hazardous, damaging to one's health and a pollutant, but it has the advantage of being sold in small portions. In several countries, distributors of solar portable lamps are partnering with savings and credit cooperative societies to provide loans to consumers who wish to purchase a solar portable lamp. (Alstone et al. 2010)

A higher focus on consumer and a better design approach has generated a new upgraded systems of SLD that present the following qualitative features:

- Limited number of functionalities in order to keep prices low.
- Simplicity in the use for inexperienced consumers.
- Energy efficiency.
- Easy to repair.
- Waste-reducing.
- Long lasting life.
- Durable and robust to resist in rugged conditions.

They present a more adaptable form factor and additional features that are more sensitive to users' needs and demands: multiple recharge options, more robust charging solutions and battery life, multiple dimming settings, charge indicators and battery life notification enabling the consumers to better ration and use correctly their lighting systems use. SLD are differentiated by typology and performances and designed to accomplish different users' needs and deliver different functional lighting performance. They can be categorized in:

Flashlights/Torches: portable handheld devices offering directional lighting at low lumen output. Today's solar torches typically feature integrated solar panels and offer the possibility to charge mobile phones and other electrical devices on the go (Table 1).

Project, Company	Image	Functions	Link
Solar LED Torch with mobile phone charging capability, Philips		• Two light levels and phone-charging capabilities. • Two levels of light: bright with 1 LED lamp switched on; very bright with 3 LED lamps on. • Two ways of charging: solar energy or manually by cranking. • Mobile phone charging function. • Maintenance-free: Long-life LED source. • Long lamp lifetime: Three LEDs >10000 hours. • Lantern housing material: ABS.	http://www.lighting.philips.com/main/application_areas/off_grid/products.wpd
D.Light 250, D.Light (2006)		• solar light and mobile charger. • bright white light by LEDs at a wide angle. • It uses a highly efficient LED. • long lasting lifetime: >50,000 hours. • four different brightness settings. • 2 hours of bright light duration. • illuminated on/off button for easy location.	http://www.dlightdesign.com/
Pico Lantern, Sunlabob		• multifunctional mobile or stationary lighting device. • resistant, lightweight, durable polymer casing. • internal components protection by a rubber sealing ring. • NiMH batteries and a high-tech internal charge controller. • tested by Fraunhofer Institute for Solar Energy Systems. • charging time is about 5 to 6 hours. • movement-free touch switches. • robust metal suspension.	http://www.sunlabob.com/solar-rechargeable-lamps.html

Table 1. Flashlight/torches solar portable LEDs lighting

Task lamps/work lights: portable or stationary handheld devices, including solar desk lamps, in a range of panel sizes and light output levels utilized for specific tasks (i.e. reading, weaving etc.) (Table 2).

Table 2. Task lamps/work portable solar LEDs lighting

Project, Company	Image	Functions	Link
Sunnan Table Lamp, Ikea		• Base: ABS plastic, Polycarbonate plastic • Reflector: Polycarbonate plastic • Protective glass: Acrylic • USD 19.99	http://www.ikea.com/us/en/catalog/products/90154371/
Solar Reading Light, Philips		• Task light: Directional LED light for reading and writing. • Fast charging: 8 hours to load 1.2V • NiMh AAA battery, 750 mAH. • Solar charge: 0.4W crystalline silicon PV. • Long usage time: Up to 5 hours with 2 LEDs. • Overcharging and deep-discharge protection. • Lantern housing material: ABS.	http://www.lighting.philips.com/main/application_areas/off_grid/products.wpd

Ambient lamps /"lanterns": portable or stationary devices that resemble the kerosene hurricane lamp form factor. They typically offer multi-directional light along with a wide variety of size and functionality depending on technology (Table 3).

Table 3. Ambient lamps or lanterns with LEDs

Project, Company	Image	Functions	Link
Kiran Solar Lantern, D.Light S10 (2006)		• Provides up to 8 hours of bright light. • durable. • Weather-resistant. • 360-degree space lighting. • Battery charge in 5.5 hours. • Price of about 10 USD.	http://www.dlightdesign.com/
Uday Mini Solar Philips		• Solar charge: 5W polycrystalline silicon PV • 6-10 h to recharge the 6V 4.5Ah SLA battery. • IP65. •Overcharging and deep-discharge protection. • hanging and portable •Lantern housing material: ABS.	http://www.lighting.philips.com/main/application_areas/off_grid/products.wpd
Nokero N200		• solar-powered hanging light bulb. • 6 hours lasting on one day's charge. • one adjustable solar cell. • four LEDs. • power of one AA-sized, 1.2 V, 1000mAh replaceable and recyclable Ni-MH battery. •automatically turns off in bright light to save energy. • multi-switch set to be high, low or off. • rainproof and durable	http://www.nokero.com
LED Solar 1, Osram (2007)		• super bright OSRAM GOLDEN DRAGON®LED. • Charge of mobile phone. • Charge time under up to 16h. • Illumination up to 7h. • Two switch set: 100% and 25%. • Output power of lantern: 1,2 W. • Hanging or Free standing with extra feet	http://www.osram.com/_global/pdf/Consumer/Luminaires/outdoor_garden__camping/TDS_EN_LED_SOLAR_I_2008-07-08.pdf

Portable recharger: semi-wearable portable lights garments systems inserts tiny solar cells inserted into shirts, woven items and bags, sometimes even produced by remote communities in developing countries in order to suit technology to true social needs with a

beneficial impact also in the productive local economies. This bags and wearable objects are able to generate lighting and also charge batteries for mobile phone in a portable, flexible and qualitative way. (Table 4).

Table 4. Portable recharger with LEDs lighting

Project, Company	Image	Functions	Link
FLAP (Flexible Light and Power), PopTech, The Portable Light Project, and Timbuk2		•portable solar bags designed for off-grid users. • incorporates a detachable solar panel. • LED reading light. • mini-USB port for charging small devices.	http://poptech.org/flap
Portable Light Project, KVA Kennedy & Violich Architecture Global Solar Energy		• simple, versatile textile with flexible PV and LEDs. • adaptable to local cultures. • customizable by people using traditional weaving and sewing technologies in an open source model. • providing bright, white light to read. • charge cell phones and other small devices.	http://portablelight.org/

Multi-functional devices: portable or stationary devices that can provide directional and multi directional light, a variety of value-added features (i.e. mobile phone recharge), and can be utilized for either task based or ambient lighting needs. (Table 5).

Table 5. Multiple functional solar portable LEDs lighting

Project, Company	Image	Functions	Link
Solar Pebble Adam Robinson for Plus Minus Solar (2010)		• PV charge during the day. • To light unfolding and twisting motion • small and portable. • bigger surface for lighting emission . • strap with magnets to hang the lamp. • lighting for outdoor and indoor environment.	http://www.plusminussolar.co.uk/
Solar Portable Lantern, Philips		•Long usage time: 48 hours on built-in LED. •Fast charging: 6 h to recharge 6V 4.5Ah SLA battery. •Light direction: Lamp holder can swivel 180 degrees; special cover is included for task lighting purposes. •Solar charging: 5W polycrystalline silicon PV. • Overcharging and deep-discharge protection. • Portable use: Contains hand grip. • Lantern housing material: ABS.	http://www.lighting.philips.com/main/application_areas/off_grid/products.wpd
Moonlight, TeamLumen for Kamworks (2009)		•Rain water proof. •Handy pole support. • Separate panel (allowing to keep lamp inside). •Flexible usage. • Long-lasting LEDs. • three light levels allow several usages during the night: 2 hours of bright light, a few hours of medium light and low light for the whole night.	http://teamlumen.blogspot.com/

Micro-SHS: lighting devices associated with a small portable solar panel that powers or charges 1-3 small lights, mobile phones, and other low-power accessories (e.g., radio, mini-fan). Solar Home Systems (SHS) are the most prominent of these small-scale alternative technologies and are designed for rural family houses to replace current solutions as car batteries. (Table 6).

Table 6. Micro SHS lighting systems

Project, Company	Image	Functions	Link
Solar Home System with mobile phone charging capability, Philips		• Fast charging: 8 hours charging time. • Solar charging: 3W polycrystalline silicon PV. • Long usage time: 10 hours with one light unit, 5 hours with both units. • Long lamp lifetime: Each unit contains 10 LED light points lasting >10000 hours. • Cable length of lamps: 3 and 10 meters for two rooms. • Mobile phone charging function: Two generic jacks included + 5V USB cable. • Overcharging and deep-discharge protection of 4V 4Ah battery. • Lamp and control box housing material: ABS	http://www.lighting.philips.com/main/application_areas/off_grid/products.wpd
Kamworks		• 20W smallest solar home system. • specifically designed just for CFL or LEDs lighting. • charging external devices as mobile phone charger or radio.	http://www.kamworks.com/
Simpanet		• Progressive Purchase™ a "pay-as-you-go" pricing to household energy systems: users pre-pay based on actual usage and each payment adds up towards the total purchase price of the solar home system. They can send payments using a mobile phone. Once fully paid, the solar home system unlocks and delivers free electricity for the expected 10-year life of the product.	http://simpanetworks.com/
Solar Home Lighting, UPS Rural Lighting System, Kotak		• AC 220V, output, 130W, Load, Portable UPS. • Wall Mountable. • Innovative Design of Housing all Components in one Housing, Plug & use type. • Low Cost Solution.	http://www.kotakurja.com/home_lighting_systems/home_lighting_systems.html

Re-sizing energy and lighting in "developed countries"

The majority of the world population is served by energy through a robust infrastructure able to assure the daily provision of electricity just by flipping a switch, clicking a remote control or even clapping hands: in developed countries, lighting, entertainment or communication in homes and offices is something taken for granted, available for people convenience without any special effort. If we think at the evolution of the domestic lighting in developed countries, we can recognize that the availability of electricity is just something new, a progress of modern society that has linked people to a centralized power generator, enabling a better quality of life while disabling the energetic autonomy that was assured by the previous technology.

"The thermolamp had merely centralized heating and lighting within the house, at a distance beyond the control of the paterfamilias. With a gas supply, domestic lighting entered its industrial and dependent stage. No longer self-sufficiently producing […], each house was inextricably tied to an industrial energy producer. [This conduced to] the loss of domestic autonomy." (Schivelbush, 1941)

The overwhelming access to electricity and the lighting dependence of developed countries results in macro-problems that are getting more and more evident: the increasing intensity of global energy consumption and the dependency to private business companies that are able to judge and decide prices and supply of energy at their own discretion. The rising costs of oil, the aggressive weather phenomena, black-outs and other emergency situations have

already shown that mature developed societies are not able to face the lack of electricity access in a quick and effective way.

From this point of view, all the previously described solutions of solar lighting systems designed for emerging nations, could offer consumers in mature societies a chance to lead more sustainable lives with self-sufficient products that enables the autonomy of energy access and also a more responsible use of it. The scenario is linked to the third industrial revolution described by Rifkin (2011) that is proposing to use renewable energies in order to build micro-grid and assure the self production and access to sustainable and shared energy. This new democratization of energy would assure a complete economical, political and relational change and would also transform the way people use lighting in private and public spaces for more qualitative lighting performance and responsible attitude toward the energy provision. The most interesting examples show that sustainable behaviours are in the micro-scale of self sufficient communities and buildings and also in the macro installation of public lighting art.

Re-ducing to Micro-grid Self Sufficient Communities

SLD examples can provide simple, cheap and well-designed solution for the lighting sustainability of developed countries: cheapness will be the driving feature for their diffusion while aesthetic and good design are the drivers for their social acceptability. The rise of LEDs, along with solar energy panels and wind energy, has encouraged many parties to start microgrids beta-site demostration: an example is EMerge Alliance that is encouraging the adoption of LEDs and solar power in order "to foster more sustainable buildings by bringing microgrids to occupied spaces, data centers, building services, and outdoor applications" (Peters, 2012). The benefits include higher lighting-system efficacy within the use of sensors and other electronic devices to increase the energy savings and to enable net-zero-energy consumption for all new commercial buildings by 2030.

Solar renewable energy could offer benefits also in the private systems of small and self-sufficient communities, but its use in homes is still far from being widespread. On the other hand, as prices of PV panels continue to drop, users and power companies are increasingly looking for new and creative applications: starting from residential solar leasing models, in which homeowners provide rooftop space for solar panels in exchange of a monthly discount on their energy bills, other companies are offering systems for creating solar-powered communities. The effort is to decrease the dependence on fossil fuels, creating self-sustainable communities, that are producing solar energy where energy is needed and used, offering also small and self-sufficient buildings: example of this are the energetic sustainable communities at local scale known as Transition Towns, a network of communities working to build resilience in response to peak oil and economic instability by collaborative behaviour, social networks and professional and technical workforces. Some Transition Towns have already started to collaborate at the local level to strategies of efficient use of resources through technological improvement, use of renewable and changes in production and consumption behaviours. An exemplar model is Brixton Energy plan that used several hundred square metres of solar panels on the top of buildings on the Loughborough Estate, working with Lambeth Council, Brixton Low Carbon Zone, United Residents Housing and the Loughborough Estate Management Board in order to generate clean green energy, reduce the estate's carbon emissions, generate a Community Energy Efficiency Fund for use in the community and provide a green investment opportunity. (Brixton, 2012)

Re-thinking Art with a social energetic role

The trend toward distributed energy capacity supports also the adoption of solar-powered outdoor LED lighting: the continued cost reduction of solar street lights and efficiency of LEDs are creating a cost-effective alternative to grid-based street lights: solar-powered lighting systems offers an opportunity of off-grid and autonomous lighting system particularly in places where grids are either inaccessible or unreliable (developing countries). Particularly interesting are the examples of developed city around the world that are exploring energy self-sufficient systems in form of public artworks giving the urban planners a new and versatile tool for sustainable energy generation into cities in both small and large scale. There is an increasing interest in designing social and environmental energy infrastructures using aesthetics and design as an ethical driver: the aim of this approach is to actualize public art trying also to educate the citizens in approving and understanding the importance of renewable energy for future uses. The example of this trend are useful to re-envision ecological relationships and even propose new models for sustainability in the modern societies, transforming in a positive and educative way the attitude of citizens toward a more reflexive and ecological behaviour into the cities. In fact, there is a certain amount of disapproval by common people toward solar or wind installations in their communities, mainly because they are considered form of visual pollution: in order to face this, the renewable art projects will define a more open attitude toward renewable energy from citizens.

Some art installations incorporates renewable energy into the design, in permanent sculpture or temporary installation, utilizing the generated efficient power to operate kinetic aspects such as movements or LEDs lighting and offering attractive, ecological, educational and participative proposals for lighting the public spaces. The aim is to change the model of society towards another in which ecological awareness takes an active part in the daily lives. As an example, CO2LED was a project temporarily inserted in the middle of a traffic island in Virginia (2007) and, with more than five hundred solar-powered LEDs on rods, it showed the way in which solar artworks could sustainably beautify urban spaces. Other examples, more similar to traditional public lighting applications are the projects Lights on a stick (2008), PowerPlant (2006) and Stuidfmeel Ideem that seem to envision the most common expression of renewable energy for public use and benefit: they captures kinetic energy of the city and sunlight to power the lighting system in a interactive and programmable way (Figure 1).

Figure 1. CO2LED (2007), Lights on sticks (2008), Solar Collector, Stuifmeel Ideeen, PowerPlant (2006)

Conclusion

Looking at the lighting for all achievement, energy efficient technologies are offering powerful and economical tools in order to design energy-efficient and more performing SLD both for developing and developed countries. Despite of this already available, efficient and quite costless solutions, the effective change toward a more inclusive and sustainable lighting

system for all depends mainly on the people acceptance, qualitative understanding, participation and education toward this transformation. From this point of view, design has an important contribution in this transformation starting from shaping the user-oriented SLD but also, more efficaciously, shaping of user behaviours, attitude and understanding toward SLD.

In addition to the technological design of more efficient systems of LEDs, PV and batteries, design is the important driver of a more effective and powerful transformation in the social and cultural dimension in order to use the technologies and access energy in a more responsible way. Inherent differences exist between the old and the new renewable means of energy productions and the change they will define in our cities, towns, quarters and homes: SLD for developing countries, the macro energy installations in the landscape and the micro-grid installations should be understood and used in a meaningful and sustainable way because the sustainability is determined by the more responsible and ecological attitude of all.

Limitations and Suggestions for Future Research

This is a starting research about the general argument of the universal access to sustainable lighting through examples and models that aim to underline the several different design challenges from the technological to the socio-cultural point of view. The heterogeneous range of collected examples is limited, partial and not conclusive: a lot of research about different other case studies, models and reference should be done in order to achieve a better and wider understanding of the subject. These preliminary example, however, are useful to understand the wide contribution of design toward the realization of the possible scenarios of sustainable and inclusive lighting and to underline that design has a positive social contribution. Future studies and closer examinations would focus on the socio-participative and energetic educational role of design toward a more eco-responsible lighting systems: how can design effectively contribute to a real and effective change toward a more responsible energetic consumption and a ecological inclusive lighting?

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