DE GRUYTER
OPEN

BUILDING RESEARCH JOURNAL

DOI:10.2478/brj-2014-0009

VOLUME 61 (2014), NUMBER 2, pp. 115 – 128

CRITICAL VIEW ON DAYLIGHTING THROUGH SOLAR BOTTLE BULB

CHEN WANG [1], FAIZUL AZLI MOHD RAHIM [1], NURUL SAFWAH MOHD YUSOFF [1], HAMZAH ABDUL RAHMAN [2], VILI HOW [1]

Daylighting is often integrated into a building as an architectural statement and for energy savings. However, the benefits from daylighting extend beyond architecture and energy savings. Solar bottle bulb is an invention that is highly effective and cost effective enough to be used in huge numbers for those without sources of interior lighting. This invention is very easy and excessively cheap, requires only a bottle, some roofing materials, water and minimal amount of regularly found chemical and no electricity is needed. This paper reviews the critical retrospect of daylighting through the solar bottle bulb perspective. It highlights the need for solar bottle bulbs use within the underprivileged areas of the world and the importance of this invention as a pathway towards sustainability. This paper presents a review on the designs, principles and applications of the invention that have startled the poor people into a new way of life. The review consists of the assessment of journals, books, newspapers, reports and online sources in the field of daylighting and solar bottle bulb.

Keywords: solar bottle bulb; daylighting, sustainability; underprivileged

1. Introduction

Light is very important for human visual activity. Without light, there will be no sight. In many of the poor yet densely populated countries, the people still live in places that are much more awful than a low cost apartment. The buildings are built very compact and closer together and therefore the free natural lighting cannot be directed into the building causing that their occupants rely thoroughly on electricity to provide lighting to the interior surrounding. Due to the poverty, these underprivileged families would rather live in an uncomfortable surrounding such as relying on burning kerosene lamps indoors, rather than paying the high-priced electricity. Because they could not afford the high cost of living, these poor people would refrain themselves from using light bulbs and thus lead themselves to live in a light-deprived environment (Sarant, 2011).

Daylighting is the practice of using natural light to provide illumination in interior environments. Before the 1940s, daylight was the primary light source in buildings; artificial lights supplemented the natural light (Edwards and Torcellini, 2002). In the short span of 20 years, electric lighting had transformed the workplace by meeting most or all of the occupants' lighting requirements. A rising problem with access and affordability of indoor lighting in developing countries has led to the renewed interest in studies of solar lights (Maillet, 2012).

[1] Department of Quantity Surveying, Faculty of Built Environment, University of Malaya, 50603 Kuala Lumpur, Malaysia, e-mail: derekisleon@um.edu.my
[2] Faculty of Science Technology Engineering & Mathematics, International University of Malaya-Wales (IUMW), 50480, Kuala Lumpur, Malaysia

The choice of using solar lighting for indoor lighting was based on a widely accepted belief that it made a positive impact on poor people's lives in developing countries, such as raising productivity for home-based crafts and improving education opportunities (World Bank, 2008; Kirubi et al., 2009; Cherni and Hill, 2009; Martinot et al., 2002). However, there are some well-known challenges around solar lighting systems, such as access, affordability, technical and maintenance difficulties (Mondal, 2010; Pode, 2010).

An invention that uses simple materials such as plastic bottles (polyethylene terephthalate (PET) bottle) filled with clean water with addition of some bleach has been created to provide lighting within houses. This invention is named as solar bottle bulb and it is fixed over the houses, acting as skylights, reflecting and amplified the rays of the sun to light up the house. This invention can provide a great amount of light by using the least amount of money as all the material needed to create the solar bottle bulb can be easily found in daily life. The purpose of this paper is to review the critical retrospect on daylighting through the solar bottle bulb. This paper presents a review on the designs, principles and applications of the solar bottle bulb by highlighting the importance of this invention towards sustainability.

2. Daylighting

The emission of greenhouse gases (GHG) during the production and use of electricity around the world is one of the major contributors to global warming. Global warming contributes to a climate change, which has the potential to damage parts of the world. Using natural lighting during the day can reduce dependence on this energy by a significant amount, potentially up to twelve hours of electricity consumption per day. It is a crucial step towards reducing the typical energy consumption with an overall impact of reducing greenhouse gas emissions in turn to ease the environment. This can be achieved by reducing the dispensable energy consumption during the daytime using the abundant sunlight, through the implementation of alternative daylighting systems for housing lighting.

Daylighting is the practice of using natural light to provide illumination in interior environments (Edwards and Torcellini, 2002). This type of lighting is useful to save energy, to avoid adverse health effects of over-illumination by artificial light, and also for sustainability. The availability of light enhances the opportunities for a better education, healthier life-style, and an extended amount of leisure time (Maillet, 2012). The nature of daylighting has not changed since its original use, but the building design has been changed. Daylighting is often integrated into a building as an architectural statement and for energy savings (Edwards and Torcellini, 2002). However, benefits from daylighting extend beyond architecture and energy. The psychological and physiological aspects of natural light should also be considered (Edwards and Torcellini, 2002). Daylight provides better lighting when compared to electrical lights, as human visual response closely matches the visual spectrum of daylight as a result of evolution. The human eye works best in light with full spectral distribution.

The comforting space and connection to the environment provided to building occupants provide benefits as significant as the energy savings to building owners and managers (Edwards and Torcellini, 2002). Daylight provides a better lighting environment than cool white or energy-efficient fluorescent electrical light sources because "daylight most closely matches the visual response that, through evolution, humans have come to compare with all other light" (Franta and Anstead, 1994). The majority of humans prefer a daylight environment because sunlight consists of a balanced spectrum of color, with its energy peaking slightly in the blue-green area of the visible spectrum (Liberman, 1991). Natural light also has the highest levels of light needed for biological functions of human body (Hathaway et al., 1992). Humans are affected both psychologically and physiologically by the different spectra provided by the various types of light (Edwards and Torcellini, 2002). These effects are the less quantifiable and easily overlooked benefits of daylighting.

Daylighting has been associated with improved mood, enhanced morale, lower fatigue, and reduced eyestrain (Edwards and Torcellini, 2002). One of the important psychological aspects of daylighting is meeting a need for contact with the outside living environment (Robbins, 1986). The physical effects of daylight such as production of vitamin D, tanning and reduced eyestrain are either caused by light reaching the retina or on the skin. At a universal level, community resilience is the ability to survive and adapt to changes in the environment and economy (Lockley et al., 2003). Previous studies show that the proper use of daylighting decreases the occurrence of headaches and eyestrain due to insufficient light levels (Franta and Anstead, 1994). These ailments are reduced when the lighting level is improved by using proper spectral light. However, the number one health problem in offices is eyestrain (Ott Biolight Systems, 1997).

A study at the North Carolina Johnston County schools specifically analyzed the academic benefits of daylighting (Nicklas and Bailey, 1997). The Johnston County schools study compared the scores of students from newly constructed daylighting schools to schools that use artificial light. Students in the daylighting schools had higher reading and math achievement scores (Nicklas and Bailey, 1997). A study by Benedetti et al. (2001) on the effects of bright artificial light on no seasonal depression substantiates benefits for patients with psychological disorders. The length of hospitalization for 415 unipolar and 187 bipolar depressed inpatients was recorded for those assigned to rooms with an eastern or western window. Bipolar inpatients in eastern rooms (exposed to direct sunlight in the morning) had a mean 3.67-day shorter hospital stay than patients in western rooms (Benedetti et al., 2001). However, no effect was seen for unipolar patients (Benedetti et al., 2001).

The modern artificial light existing today has a lighter spectrum, which is of shorter wavelength. The light of artificial lighting emits bluer wavelength than the natural sunlight and old traditional lamp such as incandescent bulb and kerosene lamp (Crisp and Elliott, 2005). Therefore, the type, intensity, and color of the lighting are important and should be considered carefully. The blue light wavelength (464 – 484 nm) is believed to be responsible for suppressing the level of melatonin (MLT) that is a type of hormone, which plays a critical role in health and well being (Crisp and Elliott, 2005; Iskra-Golec et al., 2012). Besides, working or living in a dim light condition also suppresses MLT that will direct to tumor growth (Crisp and Elliott, 2005).

A study was conducted to examine the effect of exposure to natural sunlight and level of arousal during the afternoon (Webb, 2006). It showed that natural sunlight could improve the sleepiness in the afternoon hence possibly increase performance at work. Furthermore, daytime bright light can reduce the impact of sleep loss thus sleepiness level could be lowered down and performance improved (Kaida et al., 2006). There are some previous studies confirming that daytime MLT will not change even with longer hours of higher intensity exposure (Phipps-Nelson et al., 2003). Hence, human will not feel tired by the sleeping hormone during daytime and the daylight can help in reducing sleepiness due to the sleep deprived the night before.

3. Solar Bottle Bulb

When William Gilbert coined the term electricity in the early 1600s, he was unaware of the potential it had (Gonthier, 2014). Over 200 years later, Humphry Davy designed the first functional incandescent light strip in the form of an arc lamp, a primitive form of the common light bulb (Gonthier, 2014). Although the lamp was illuminated only a short time, Davy had initiated the development of one of the most common products of the modern world (Incandescent Lamps, 2010). Light bulbs, which are now found in almost every major structure, have significantly changed humans' way of life. Different types of light bulb have different characteristics in lux intensity, spectral, energy, illuminance and its energy. At the beginning Thomas Edison was working on a practical light bulb, which is today known as an incandescent light bulb after much improvement with latest finding and technology. After that invention, there are more light bulbs that have been produced as shown in Table 1 (Bullough et al., 2012).

Table 1. Types of light source and characteristic (Bullough et al., 2012)

Category of Light Bulb	Types	Efficacy (lm/W)	Life (hours)	Color Temperature (K)	On set time
Incandescent	General service Reflectorized Tungsten-halogen	12 – 20	750 – 4000	2700 – 3200	0.1 – 0.3 s
Fluorescent	Compact Fluorescent Lamps (CFLs) T8 bulb	60 – 100	10,000 – 30,000	2700 – 7500	1 – 60 s
High Intensity Discharge	Metal halide High-pressure sodium Low-pressure sodium Mercury vapour	80 – 110	10,000 – 20,000	2800 – 5000	60 – 300 s
LED	Light Emitting Diodes (LEDs)	90 – 130	50,000 – 100,000	3000 – 8000	10 – 20 ns

3.1. The Needs of Daylighting for Underprivileged Community

There are a lot of new inventions and technologies related to light bulbs, but none of them exactly fit to the people in poor countries due to the cost to bare these technologies. These poor people are relying on artificial lighting all the time because their houses are closely built to each other to accommodate densely populated people. Hence, the surroundings are not able to be well lit by natural sunlight, causing them depend greatly on artificial lighting in the house as well as burning fossil fuel such as kerosene which is dangerous if not monitored properly. Poverty is the main reason for not applying this technology in their life. Many people could not afford to buy the expensive light bulbs, as well as electric tariff, which are very costly. Besides, these poor families mostly live in slum areas, which do not have registered electricity meter with legal connection. Most of the time, they do illegal connection which is against the laws and if caught they would be fined more than the standard rates (Oshima, 2011). Figure 1 shows the slum housing areas which owing to some structural constraints are built so close to each other and one at the top of another (Inquirer.net, 2013; HubPages, 2013). The houses typically do not have windows.

Figure 1. Manila slums in Philippines (Inquirer.net, 2013; HubPages, 2013)

A slum is a cluster of compact, overcrowded settlements of households, which is growing in an unhealthy condition in an unsystematic way, with poor structural quality of housing. It may differ in different countries but commonly slums are populated with many low socioeconomic status residents and they may even depend on some recycle trash or some informal economy work for living. Light bulb and electricity have a close relation with each other as most of the light bulbs rely on the resource to light up the light bulb. Basically, the main factors in the poor people's decision towards the solar bottle bulb were whether the invention had easy maintenance and low cost. With solar lights, the cost is not important since there are no expenses for electricity (Maillet, 2012). Regression in the area of electricity for rural communities has created a surge in solar lights (Agarwal, 2005).

3.2. Development of Solar Bottle Bulb

The luminous nodules called light bulbs are an invention that is simple and cost effective enough to be utilized in huge numbers in underprivileged areas of the world (Gonthier, 2014). The invention is a highly effective and excessively cheap option for those without other sources of indoor lighting (Gonthier, 2014). The device requires only a bottle, some roofing materials, water, and minimal amounts of commonly found chemicals; no electricity is needed (Maillet, 2012).

The idea of using plastic bottle for daylight was first created in Brazil by Alfredo Moser in 2002 (Alex, 2013). He is a mechanic who was looking for a way to substitute the electricity light using a bottle of water when Brazil was having difficulties in energy crisis and blackout. With an application of simple physical theories – simple total internal reflection and the Snell's Law, lighting into the living space could be better than allowing an opening hole in the roof. It was believed that the solar bottle bulb could produce equivalent to 55-watt incandescent bulb which can brighten the living space (Tom, 2011). However, to date there is no a sturdy source that can describe the actual luminance. The most reliable sources stated that the light produced by solar bottle bulb has equivalent to the range of 40 to 60 watt incandescent bulb depending on the weather condition (Fonseca et al., 2013).

The first solar bottle bulb was fabricated in Brazil in 2002; yet it was not known to the world until the MyShelter Foundation in the Philippines took an interest in the idea and worked together with students from the Massachusetts Institute of Technology to report it to the world in 2006 (Wang et al., 2013). The project is named “A Liter of Light” or locally called “Isang Litrong Liwanag”. The project is an environmental-friendly, zero carbon-emitting alternative to the daytime use of incandescent light bulbs and kerosene. This project is a sustainable lighting project, which aims to bring eco-friendly solar bottle bulb to unprivileged communities around the world to light up their homes.

The plastic bottles and the other materials used in the technology are easily available eliminating the need for energy-intensive processes involved in gathering, manufacturing and transporting new bottles. Although this eco-friendly bulb could only supply daylight into the living space during the day, it has a great positive impact on the life of poor people as it is cost saving because the material used is cheap, easy to find, easy to install and most notably sustainable and environmental-friendly. In addition, this bulb also makes the home a safer place to live as it reduces the risk of fatal fire incident due to the use of candle or potential dangerous electrical connection which may cause destruction and explosion.

“A Liter of Light” project has been officially announced as carbon-reducing project by the United Nations Framework Convention on Climate Change (UNFCCC) on 22 November 2011(UNFCCC, 2014). To date, solar bottle bulbs have lighted more than 120,000 homes in Philippines and 350,000 globally shared to nations such as India, Indonesia, Peru and Switzerland. During the Solar Revolution Pavilion on 24 April 2013 in Manila, Philippines, Illac Diaz, the founder of this project showed an improved innovation of solar powered bottle bulb (Figure 2) which has a small solar panel attached to generate electricity and provide possibility of having electric powered solar bottle bulb during the night time (Little of Light, 2014).

Figure 2. Filipino entrepreneur and activist Illac Diaz shows Solar powered bottle bulbs outside the first solar pavilion made from recycled materials in Manila (Little of Light, 2014)

Figure 3. Solar bottle bulbs attached on the roof provide lighting during day time (Mifunedumaguate.com, 2014)

Nowadays, the solar bottle bulbs are not only used by poor people but there are some people who took initiative to install solar bottle bulbs in their buildings. For example, one Japanese restaurant named “Mifune Japanese Restaurant” in Dumaguete, Philippines used solar bottle bulbs (Figure 3) to provide lighting within their restaurant (Mifunedumaguate.com, 2014). As it was greatly introduced over the world, some students and interested parties had made their innovation through various methods but shared throughout the Internet. Figure 4 shows one of the significant innovations when a small solar panel is mounted beside the bottle bulb to charge up the light for the night usage (Julius, 2012).

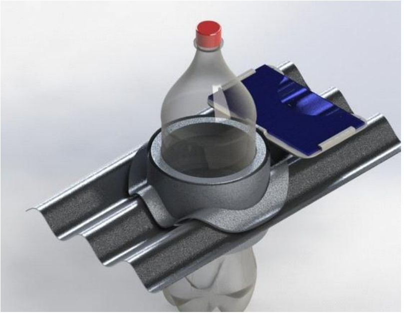


Figure 4. Innovative design of solar bottle bulb with attached solar panel (Julius, 2012)

The solar bottle bulb is quite easy to make and affordable. The materials needed to construct these solar bottle bulbs are a polyethylene terephthalate (PET) bottle (with volume of 1.5 L or 2.0 L), a piece of galvanized iron sheet, a rubber sealant to seal the bottle to the sheet metal, a little of filtered water and a capful of household chemicals such as bleach (Alex, 2013). The rationale of the bleach is to prevent any bacterial growth within the bottle while the water acts to scatter the light.

3.3. How Solar Bottle Bulb Works

The solar bottle bulb installed on the roof works by making the use of simple physical theory, the refraction of light rays. The refraction of light rays occurred because of two different media involved, which are the air and water. Figure 5 demonstrates how the solar bottle bulb works to create illumination. By putting a water-filled container in the hole we can collect more light due to two fundamental optical effects, which are the Snell's Law and total internal reflection (Bernard, 2012). It has been mentioned that the stream of light passes through the bottle and facing with refracting bending and internal reflecting to produce bright light source. That situation is very useful to get a more light to go down through the hole. There are similar physical phenomena such as the light refraction and reflection in diamond.

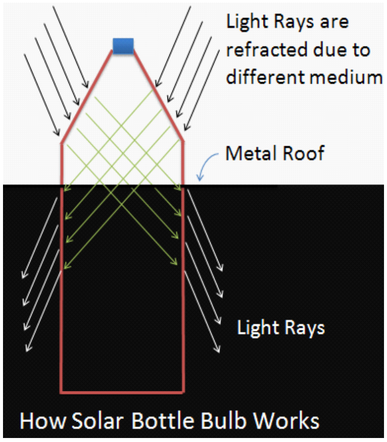


Figure 5. How solar bottle bulb works

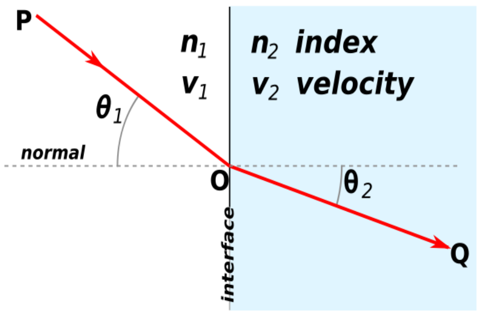


Figure 6. Refraction of light at the interface between two media of different refractive indices, with $n_2 > n_1$ (Alex, 2013)

According to the Snell's Law, when the light is moving through the air encounter with a denser media like water, it changes the direction due to the changing index of refraction. Figure 6 illustrates how the light ray "bends" when it runs into water surface so that it is traveling more directly down into the water. The simplest case of refraction occurs when there is an interface between a uniform medium with index of refraction n_1 and another medium with index of refraction n_2. The Snell's Law describes the resulting deflection of the light ray:

$$n_1 \sin \theta_1 = n_2 \sin \theta_2$$

where θ_1 and θ_2 are the angles between the normal (to the interface) and the incident and refracted waves, respectively.

This phenomenon is also associated with a changing speed of light as seen from the definition of index of refraction provided above which implies:

$$v_1 \sin \theta_2 = v_2 \sin \theta_1$$

where v_1 and v_2 are the wave velocities through the respective media.

Despite this situation, some of the light will still be on a path to the opposite side of the cylinder. A portion of the light is trapped in the cylinder (solar bottle) because of simple reflection, which occurs at anytime the light passes from one transparent material to another. However, during most of the day, the light will strike the cylinder walls in such a way that lots of light will be reflected down towards the hole (Alex, 2013). This phenomenon is called total internal reflection. The light reflected this way will bounce back and forth as it travels down through the water column, more like signals passing through an optical cable. Figure 7 shows comparison between how much sunlight will be collected when using the solar bottle and without using it. Without a solar bottle bulb, only a small amount of sunlight would be collected. With only one opening on the roof, the sunlight may not be able to be projected or refracted into every corner of a room space but only be able to pass straight through illuminating a spot on the floor or wall. After additional plastic bottle filled with water, the sunlight can be refracted in many directions according to the Snell's law and internal reflection (Alex, 2013).

By refracting light from the sun, the solar bottle bulb can produce the light 360 degrees around the room with equivalent light power of 60 -Watt bulb.

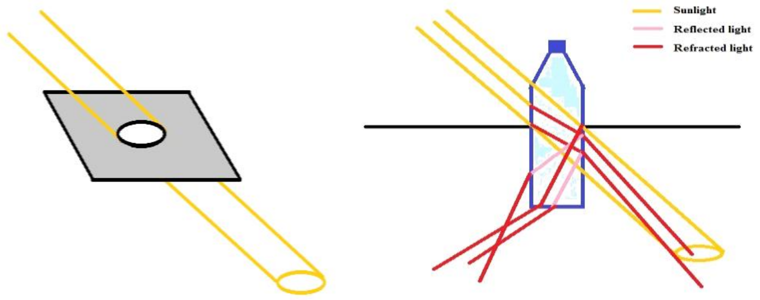


Figure 7. Illustrating how much sunlight will be collected when using the solar bottle and without using it (Alex, 2013)

Table 2 below shows the differences between the solar bottle bulb and conventional bulb. The solar bottle bulb will last for five years without maintenance and before the water has to be changed. Table 3 shows the advantages and disadvantages of using solar bottle bulbs.

Table 2. The differences between solar bottle bulb and conventional bulb (UNFCCC, 2014)

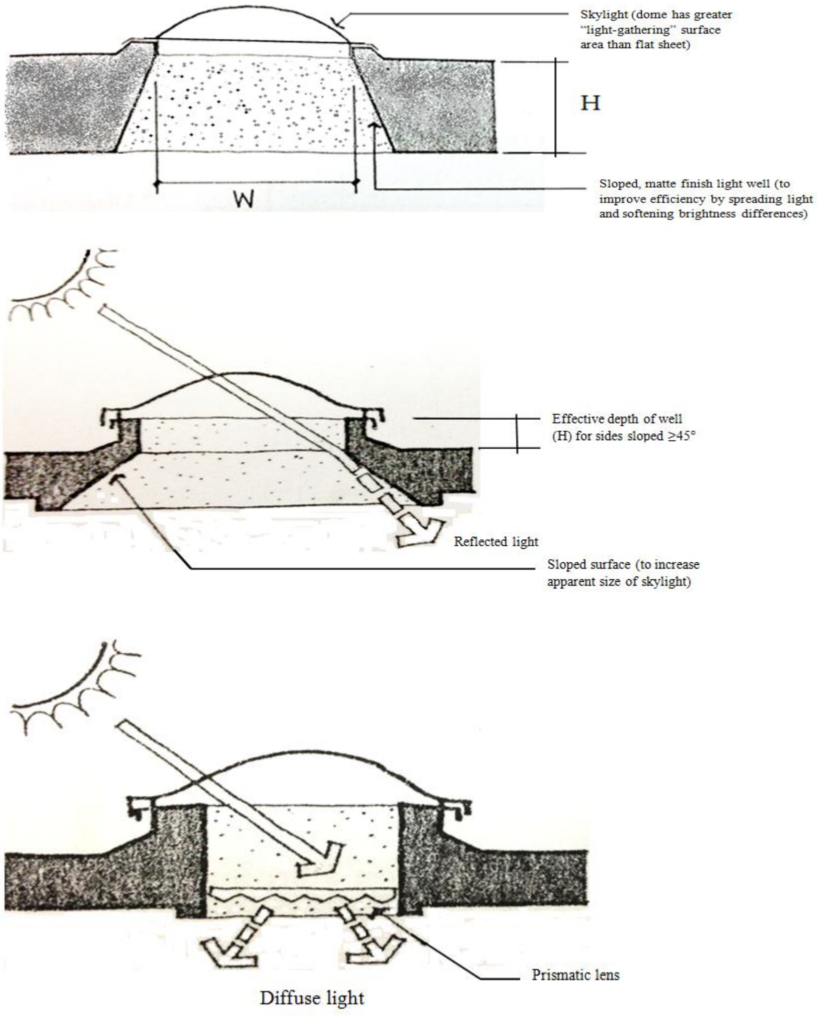
Solar Bottle Bulb	Conventional Bulb
Refractive light: 60 Watts on clear day Coverage: light propagate 360 degree in 40 square meter Heat by the light: Close to zero Cost: < $1 Saving: $6 per month	Carbon footprint: 0.45 kg CO_2 Heat by the light: 90% of power consumed emitted as heat energy Usage: 50 Watts run for 14 hours a day Electricity consumption: – approximate 0.77 kg CO_2 per kWh – 16.17 kg CO_2 per month – 200 kg CO_2 per year

Table 3. Advantages and disadvantages of solar bottle bulb

Advantages	Disadvantages
Natural lighting No glare Cheap material Environment friendly (Zero emission, less pollution) Can be changed easily Reduces fatal accident such as fire hazard No additional charges such as electric bills	Not very durable Needs constant monitoring Only applicable during day time Not effective during low light day such as cloudy day and overcast sky

3.4. Comparable Lighting Concept

The solar bottle bulb applied similar concept as light wells and solar pipe but with density content in between to improve the short coming of roof structure comparing to new product manufacturing as mentioned above. The illustration shows how it works (Figure 8), in considering the reflectance of light (Egan and Klas, 1983).



Note:
Double-dome acrylic skylights can have translucent glass-fiber insulation in air space to provide diffuse light and increase resistance to heat flow. However, these luminous ceiling elements could be perceived as being dull and gloomy

Figure 8. Pyramidal well (Egan and Klas, 1983)

The illustration demonstrates that solar bottle bulb has similar concept as these light wells. Therefore, the solar bottle bulb can direct light into the room with diffuse light due to water density and plastic sheeting which encourages reflection and refraction.

4. Conclusions and Recommendation

There are a lot of different models and technologies about daylight illumination that exist these days, from models as simple and compact as a PET bottle filled with water, to more complicated technologies such as hybrid lighting systems. Different solar lighting technologies are applicable to different types of buildings. The accessibility of light can improve the chances for a better life. Many urban areas have a good access to electricity, while rural areas do not. A growing problem with access and affordability of indoor lighting in developing countries has led to the renewed interest in studies of solar lights. With solar lights, the cost is not important since there are no expenses for electricity. The solar bottle bulb can provide sufficient lighting to a room without transmitting much heat into the interior. The color of light delivered by the solar bottle bulb is close to that of sunlight. Solar bottle bulbs will be easily accessed and removed from the roofs of households if the bleach in the bottle does not keep the mixture clean from algae and solar bottle bulbs are most effective during daytime. However, the drawbacks of solar bottle bulb are it did not perform well when the weather was overcast and when it was raining.

Despite these positive aspects of the solar bottle bulb, there were people who did not believe its ability to provide lighting, partly because there were no published experiments providing precise data regarding the characteristics of light produced by these bulbs. Also, there are remarks from some users who have installed solar bottle bulbs commented that the solar bottle bulb did heat up the room. Further comprehensive studies are needed in the future so that more advanced solar bottle bulbs technology can be designed with different materials and different structures. It would be very remarkable if a different solar bottle bulb can be designed that could be used during the hours of the night. This invention would have to be more complex, as it would have to somehow store the sun's energy for the nighttime use. There is the possibility that this may not even be possible because of the use of inexpensive, recycled materials. In this case, a household in a developing country would have one solar bottle bulb to use during the day and another solar bottle bulb to use during the night. There is also the possibility that there could be one light with both functions during the day and during the night.

References

[1] Agarwal, S. G., Barnes, D.F. and Cabraal, R. A. (2005), "Productive Uses of Energy for Rural Development" [electronic version], Annual Review of Environment and Resources 30, 117-144.

[2] Alex (2013), The Solar Bottle Bulb Revolution, available at: http://sustainablevision.org/index.php/the-solar-bottle-bulb-revolution/ (accessed June 8, 2014).

[3] Benedetti, F., Colombo, C., Barbini, B., Campori, E. and Smeraldi, E. (2001), "Morning sunlight reduces length of hospitalization in bipolar depression", J Affect Disorder 62, 3, 221-223.

[4] Bernard, B. (2012), Innovative "Solar Bottle Bulb" Lighting the Darkness with the Help of Bleach Disinfectant, Water Quality and Health, available at: http://www. waterandhealth. org/innovative-solar-bottle-bulb-lighting-darkness-bleach-disinfectant/ (accessed February 27, 2013)

[5] Bullough, J. D., Rea M. S. and Zhang X. (2012). "Evaluation of visual performance from pedestrian crosswalk lighting", Transportation Research Board 91st Annual Meeting, Washington, DC, January 22-26. Washington, DC: Transportation Research Board.

[6] Cherni, J. and Hill,Y. (2009), “Energy and policy providing for sustainable rural livelihoods in remote locations – the case of Cuba”, Geoforum 40, 645-654.

[7] Crisp, J., and Elliott, B. (2005), Introduction to fiber optics. Optic Fiber and Light – A Brilliant Combination (3rd ed.), Elsevier.

[8] Edwards, L. and Torcellini, P. (2002), “A Literature Review of the Effects of Natural Light on Building Occupants”, Technical Report, National Renewable Energy Laboratory, U.S. Department of Energy Laboratory, NREL/TP-550-30769.

[9] Egan, M. D. and Klas, R. H. (1983), Concepts in architectural lighting, New York, McGraw-Hill.

[10] Fonseca, R. W., Didone´ E. L. and Pereira F. O. R. (2013), “Using artificial neural networks to predict the impact of daylighting on building final electric energy requirements”, Energy and Buildings 61, 31-38.

[11] Franta, G. and Anstead, K. (1994), Daylighting Offers Great Opportunities, Window & Door Specifier – Design Lab, Spring, 40-43.

[12] Gonthier, A. (2014), The Bright idea That Changed Everything, available at: http://www.scientireview.org/pdfs/372.pdf (accessed June 8, 2014).

[13] Hathaway, W. E., Hargreaves, J. A., Thompson, G. W. and Novitsky, D. (1992), A Study into the Effects of Light on Children of Elementary School Age – A Case of Daylight Robbery, Alberta: Policy and Planning Branch, Planning and Information Services Division, Alberta Education.

[14] Incandescent Lamps (2010), Retrieved June 10, 2014 from http://www.edisoncenter.org/incandescent.html#hist

[15] Iskra-Golec, I. M., Wazna, A., and Smith, L. (2012), “Effects of blue-enriched light on the daily course of mood, sleepiness and light perception: A field experiment”, Lighting Research and Technology 44, 506-513.

[16] Julius. (2012), Solar bottle design. Retrieved from http://grabcad.com/library/julius-solar-bottle-design

[17] Kaida, K., Takahashi, M., Haratani, T., Otsuka, Y., Fukasawa, K., and Nakata, A. (2006), “Indoor exposure to natural bright light prevents afternoon sleepiness”, SLEEP-NEW YORK THEN WESTCHESTER 29, 462.

[18] Kirubi, C., Jacobson, A., Kammen, D. and Mills, A. (2009), “Community-based electric micro-grids can contribute to rural development: evidence from Kenya”, World Development 37, 1208-1221.

[19] Liberman, J. (1991), Light Medicine of the Future, New Mexico, Bear & Company Publishing.

[20] Little of Light (2014), A little of light official website, available at: http://aliteroflight.org/index.php (accessed June 9, 2014).

[21] Lockley, S. W., Brainard, G. C., and Czeisler, C. A. (2003), “High sensitivity of the human circadian melatonin rhythm to resetting by short wavelength light”, J Clin Endocrinol Metab 88, 4502-4505.

[22] Maillet, R. (2012), Liters of Light: Engineering a New Soda Bottle Solar Light, available at: http://www.scientiareview.org/pdfs/226.pdf (accessed June 10, 2014).

[23] Martinot, E., Chaurey, A. and Lew, D. (2002), “Renewable energy markets in developing countries”, Annual Review of Energy Environment 27, 309-348.

[24] Mifunedumaguate.com (2014), The MIFUNE one liter light project. Retrieved from http://www.mifunedumaguete.com/www.mifunedumaguete.com/a_liter_of_light.html

[25] Mondal, A. H. (2010), “Economic viability of solar home systems: case study of Bangladesh”, Renewable Energy, 35, 1125-1129.

[26] Nicklas, M. G. and Bailey, G. B. (1997), “Daylighting in Schools”, Strategic Planning for Energy and the Environment 17, 41-61.

[27] Oshima, K. (2011), Plastic bottle light up lives. Retrieved February 13, 2013 from http://edition.cnn.com/2011/WORLD/asiapcf/08/30/eco.philippines.bottle/index.html

[28] Ott Biolight Systems, Inc. (1997), Ergo Biolight Report, California: Ott Biolight Systems, Inc.

[29] Phipps-Nelson, J., Redman, J. R., Dijk, D. J., and Rajaratnam, S. M. (2003), “Daytime exposure to bright light, as compared to dim light, decreases sleepiness and improves psychomotor vigilance performance”, Sleep 26, 6, 695-700.

[30] Pode, R. (2010), “Solution to enhance the acceptability of solar-powered LED lighting technology”, Renewable and Sustainable Energy Reviews 14, 1096-1103.

[31] Rea, M. S. (2014), “The lumen seen in a new light: Making distinctions between light, lighting and neuroscience”, Lighting Research & Technology 0, 1-22, DOI: 10.1177/1477153514527599.

[32] Robbins, Claude L. (1986), Daylighting Design and Analysis, New York: Van Nostrand Reinhold Company; 4-13.

[33] Sarant, L. (2011), The World’s Cheapest Light Bulbs are Plastic Bottles. Egypt Independent. Retrieved Feb 2, 2013 from http://www.egyptindependent.com/news/worlds-cheapest-light-bulbs-are-%E2%80%A6-plastic-bottles.

[34] Tom (2011), Solar Bottle Bulb: Discarded Bottles Help Provide Light to Millions of Poor Homes, Retrieved February 3, 2013 from http://www.urbanghostsmedia.com/ 2011/ 09/solar-bottle-bulb-discarded-bottles-provide-light-millions-poor-homes/

[35] UNFCCC (2014), Momentum for Change “A Little of Light”, United Nations Framework Convention on Climate Change Website, available at: http://unfccc.int/secretariat/ momentum_ for_change/items/6638.php (accessed June 8, 2014).

[36] Wang, C., How, V. L. and Abdul-Rahman, H. (2013), “The performance of solar bottle bulbs at different interior exposure levels, Lighting Research and Technology” 0, 1-12.

[37] Webb, A. R. (2006), “Considerations for lighting in the built environment: Non-visual effects of light”, Energy and Buildings 38, 7, 721-727.

[38] World Bank (2008), Issues note of the RETToolkit, RETToolkit: a resource for renewable energy development, Washington, DC.

[39] HubPages (2013).

[40] Inquirer.net (2013).