ISSN 2250-3153

Sky-lighting- A solution to reducing energy consumption in Apparel Sector

Pavan Godiawala*, Noopur Anand, Jayantilal Mathurbhai Patel*****

*National Institute of Fashion Technology Gandhinagar, Department of Fashion Technology
**National Institute of Fashion Technology New Delhi, Department of Fashion Technology
***L. D. College of Engineering, Department of Mechanical Engineering

Abstract- Abundant, eco-friendly, continuous and free, source of day lighting has a potential to reduce the consumption of 20% of lighting load of a garment factory. Various models of daylight harvesting have been experimented with in various production floors with great success. Apart from obvious advantage of energy conservation, harvesting of sunlight has many industrial advantages as well as positive impact on psychological and physiological health of workers in apparel sector. Implementing daylight harvesting solution has many challenges starting from consistency of the sunlight throughout the day& round the year, penetration of light in vertical structure &deep regions, apart from commonly known issues of glare and radiation. This review paper discusses all aspects of day light harvesting.

Index Terms- Day lighting, Apparel Manufacturing, Lighting, Sustainable Energy, Energy harvesting

I. Introduction

Energy is driving force in every sector of economy and industrial sector accounts for almost half of the total energy used around the globe. In India consumption of energy has increased from 28 % to 65% in last 50 years. India has an installed power capacity of 236.38 GW energy1and still people do not have proper access to electricity. Per capital primary energy consumption in India is 0.38 TOE (ton of oil equivalent)against the global average of 1.29 TOE one of the lowest in world.

The Indian textile and apparel sector is the second largest employer employing 35 million people2in more than60,000 garment manufacturing units has substantial demand on energy which will only increase in future looking at its prospects of growth after MFA and the current policies emphasizes on SME's modernization.

It is paramount for survival of industrial sector to match the energy growth to keep a pace with 8% -10% GDP growths. Currently the biggest challenge faced by the production sector is large gap between energy demand and energy availability as industrial growth is faster than energy growth. Additionally Each Kilowatt of increased energy also causes carbon emission hence has negative impact on environment. So to improve economy there is a need to increase production, which needs more energy, which will in return have negative impact on environment. There is only one solution to this situation that is to increase energy efficiency by having a clean pollution free source of energy at affordable cost.

Energy efficiency usually refers to a reduction in energy consumption for the given service (manufacturing process, lighting, etc.). Making technical changes in the machinery process or finding alternate method of energy can do this reduction in energy. Using natural resources for clean and green energy to reduce the dependency on conventional energy requirement is also a very important part of energy efficiency measure.

II. Energy Consumption Patterns of Indian Textile & Apparel Sector

For a typical 100 machine factory, energy consumption for cutting room is 15%, for sewing activities 33%, for washing 34%, 38% for finishing and 14% lighting load. Finishing room consumes 4Kg of steam per hour per ironing table whereas washing consumes 7-8 Kg of water/denim.

Table 1: share of energy consumption and cost in various textile sectors

Textile Sector	Electrical Energy(KWh/Kg)	Fuel (HO), L/kg	Total Energy Cost $/Kg
Spinning	3.60-3.80	-	0.19-0.20
Knitting	0.30-0.40	-	0.02
Weaving	2.0-2.20	0.02-0.03	0.12-0.13
Dyeing & Finishing	1.60-1.70	0.6-1.00	0.30-0.45
Clothing M/fing	0.80-1.0	0.1-0.2	0.07-0.12

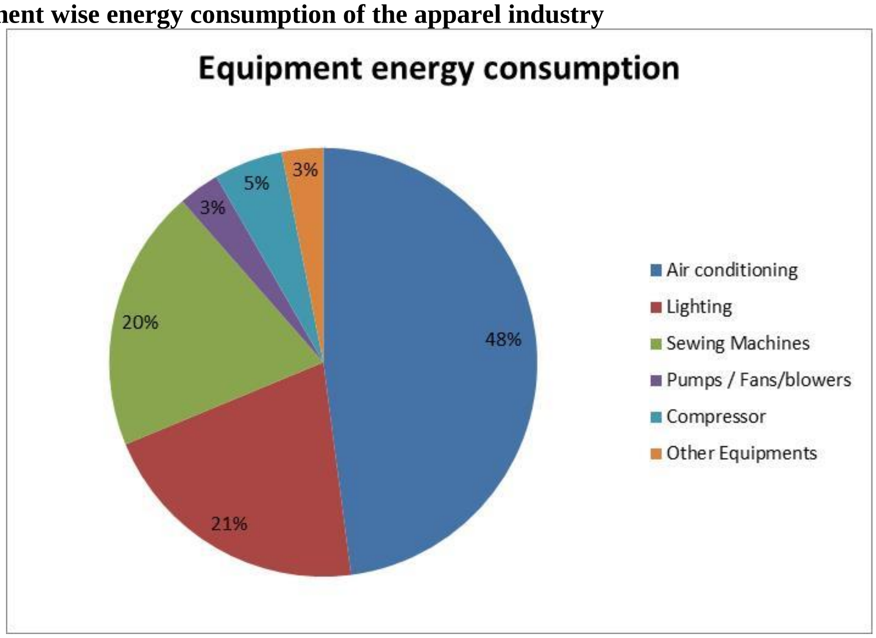
Source: Energy saving strategies in textile industry – The case study of Mauritius

Table 2: The equipment wise energy consumption of the apparel industry

Equipment	Energy Consumption (%)						
	F1	F2	F3	F4	F5	F6	Avg.
Air conditioning	51	44	45	42	45	50	46
Lighting	26	16	22	17	25	16	20
Sewing Machines	12	13	21	24	17	26	19
Pumps / Fans/blowers	5	6	2	3	2	1.5	3
Compressor	4	4	5	9	7	3.5	5
Other Equipment	2	2	4	5	1	3	3

(Note: The data collected is from 6 different garment manufacturing units with a capacity of over 100 machines from Gujarat, depicted as 'F1 to F6')

Chart 1: The equipment wise energy consumption of the apparel industry



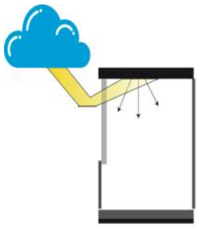
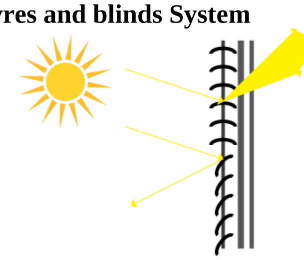
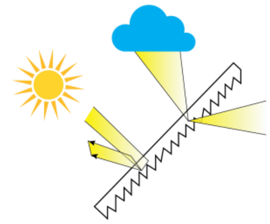
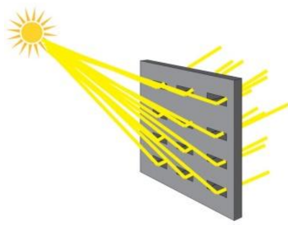
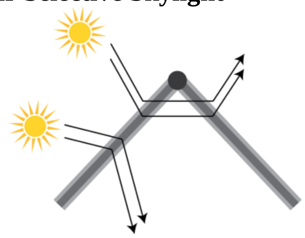
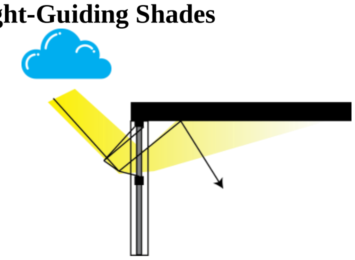
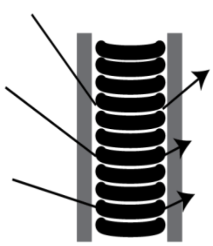
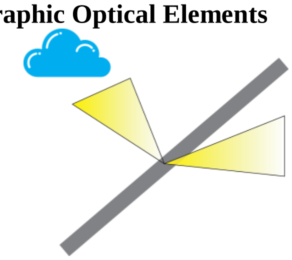
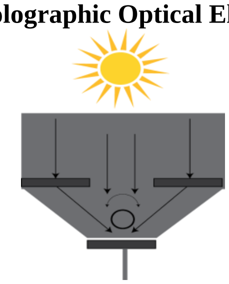
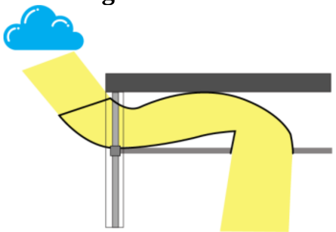
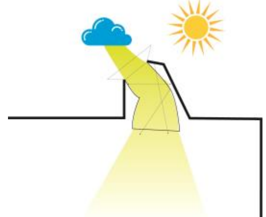
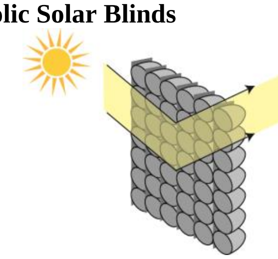
Source: Comparative Study of Energy Assessment from Apparel Industries

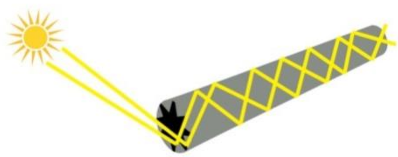
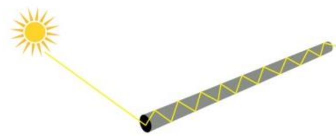
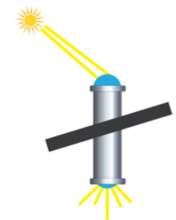
The above study shows that after air conditioning, machines and lighting which are next biggest consumer of power and each account for around 1/5thof the total energy consumption. Much work has been done in improvisation and improvement of technology of sewing machines i.e. to reduce the power consumption of machines starting from replacing clutch motors by servo and to semi direct drive to direct drive motors. But development in the area of lighting is very limited.

There are many methods of harvesting skylight and bringing it in to the production floor to make energy consumption more efficient

III. Options Available for Daylight Harvesting

Effective use of daylight into interior of building is buzzword and latest concept used by green building consultants, architectures and other associated experts. It has become a way to get associated with words like green building, sustainable energy conservation, carbon credit, recyclable 4R, ecological and many more words. Daylight harvesting system classify into two major categories – harvesting and transmitting daylight in its light form or converting and transmitting solar energy in electricity form. A very common example of converting solar power to electricity for transmission is Photo Voltaic Cells or Solar Cells which although are widely used, have major financial implications and environmental liabilities. In this article author intends to explore the various existing solutions where daylight is collected and transmitted in its light form.

Light Shelves  Light shelves mounted horizontally on window with pivot fixing and panels. It directs light to the ceiling by reflecting it from the panels and illuminates the room.	**Louvres and blinds System**  Louvers and blinds system have horizontal or vertical slats which range from simple to sophisticated combinations and surface finishes. They redirect light directly to the room as well as ceiling.	**Prismatic Panels**  Prismatic panel is a saw tooth device functional in redirecting or refracting the incoming sky light. It redirects direct sun light but transmits the diffused light incident on surface, reducing glare substantially.
Laser-Cut Panels  Laser cut panels are made of clear acrylic sheets that are cut in thin panel arrays acting as small internal mirrors, deflecting the incident light to the required space.	**Angular Selective Skylight**  Angular selective skylight redirects the high elevation light being incident on the surface but transmits the low elevation light. This renders the system a quality of providing stable irradiance for longer day duration.	**Light-Guiding Shades**  Light-guiding shades redirects the sky light to ceiling by the usage of deep external shading with two reflecting surfaces and a diffusing glass element which makes possible the transmittance of diffused light into the building.
Sun-Directing Glass  Sun-directing glass is composed of concave PMMA structure stacked between double glazed glass units and sealed, transmitting diffused light to the room.	**Zenithal Light-Guiding Glass with Holographic Optical Elements**  Zenithal light-guiding glass redirects the zenithal zone day light to the building by a polymeric film with holographic diffraction grating.	**Directional Selective Shading Systems using Holographic Optical Elements**  Directional selective shading systems are embedded with holographic diffraction gratings, to reject incident light from areas of sky with acute angle simultaneously transmitting diffused light from other directions.
Anidolic Ceilings  Anidolic ceiling has external installation of parabolic collector and light directing duct	**Anidolic Zenithal Openings**  Anidolic zenithal opening is linear non-imaging parabolic concentrator placed on	**Anidolic Solar Blinds**  Anidolic solar blind is a grid of hollow reflective elements each having parabolic

with reflective lining, transmitting daylight to remote areas of room and dispersing by parabolic reflector at exit aperture.	roof, facilitates the collection of light from a wide vault of sky between northern horizons to equinox position of sun.	concentrators of three dimensional shapes. It reflects direct light from high altitude and transmits light collected from low solar angle which is diffused in nature.
Hollow Prismatic Pipes  Hollow prismatic pipes are made of prism shaped mirrored light pipe. Incident collimated light beams undergo refraction and total internal reflection propagating to the desired length.	**Solid Core Lighting Systems**  Solid core lighting systems are flexible or rigid rods transmitting focused beam of light to remote locations by total internal reflection with minor transmission loss.	**Light Pipes**  Light pipes are tubular structures with convex light collectors and reflective internal surface, installed on roof to transmit light to the room below.

Various other models of daylight harvesting and transmission also exist commercially working on similar principle where light is collected and transmitted to a desired level and location. It works on the principle where fading luminosity of daylight is complimented by gradually illuminating artificial light during the day span. This system has luminosity sensors which maintain the lux level of the desired space by sensing the contributed illumination of daylight and in concurrence powering the artificial light adequately.

IV. ADVANTAGES OF DAY LIGHT HARVESTING

Health advantage

The spectrum of sunrays has certain direct and indirect effects; such effects are evidently mediated by photoreceptors in eyes and involve the brain and neuron-endocrine organs. Sunlight relates to all living beings by an inbuilt biological clock known as circadian rhythms, which is controlled by melatonin hormone produced during sleep at night. Deprivation of sunlight affects this cycle and thus leads to lack of sleep, low alertness, seasonal depression, immune loss or in extreme cases increase in malignant tumor growth. In garment factories long work hours deprive the workers of the sunlight. Various case studies of garment industry in Fiji and Bangladesh clearly reflect that the garment factory workers are facing problems of high level of fatigue, rhythmic work, obesity, depression[3]. This can be addressed by bringing the daylight to the factories.

Additionally sunlight is the only source that provides vitamin-D and prevents grave diseases like cancer, diabetes, weight loss and helps absorb calcium. The artificial lighting systems used around commonly are not a very safe haven, studies suggest that all incandescent and fluorescent lights emit EM waves which are carcinogenic to humans[4], so considering artificial light to be a substitute to daylight can be harmful not only to the human body but also adversely affect environment on disposal as they are non-biodegradable in nature[5].

Thus psychologically and physiologically it is important to admit daylight into the buildings, as it provides a very pleasant and hygienic atmosphere.

Industrial advantage -

Color management is a very critical process in apparel manufacturing which is majorly governed by visual judgment of the onlooker. Color rendering index (CRI) of a light source is a value which defines the perception of color of an object is the given light, making CRI a measure for light quality. Apparel manufacturing units usually have white lights which has a CRI value of 0.7 – 0.8 whereas sunlight has a CRI value of 1 which makes it more favorable for the process and result in early identification of shade variation problems eliminating rejection at final inspection stage.

In sewing room also, adoption of sunlight helps in performing critical sewing process by increasing visual contrast between fabrics and thread providing better clarity specially in the cases where thread color and fabric color are matching and the seam has critical stiches like 1/8 or 1/16 edge stitch, ditch stitch etc. This will result in lower fatigue and improved comfort level thus better productivity and low rejections[6].

Also, the natural light prevents fungal and bacterial growth on fabric in store department in long term storage. The advantages of daylight is improved working conditions and environment over and above the fundamental reduction of usage of artificial light and contributing towards low running cost.

V. CASE STUDY

Case I – Brandix Factory

In a case study of Bandix , sunlight was effectively utilize by channeling the light into the work space by using zenithal daylight harvesting system for general lighting by providing openings in ceiling zenithal points and positioning workstations near building facades having potential of harvesting longer duration of daylight and used additional LED light for task work at sewing points. This reduced the total electric energy requirement by 10%.[7]

Figure 1: Brandix Factory daylighting system[8]

(Source: Towards a sustainable industrial system, with recommendations for education, research, industry and policy)

Case II - German Bayer factory

In the German Bayer factory, a case study presented by ECBCS about the Bayer Nrodic Headquarter Norway building which has a 'L' shaped building with an atrium following the long axis of both the wings, which has mostly single and double occupancy offices A bidirectional day light system was used in which the day light was not entering only through the both side façade windows placed near the ceiling but also through a glaze door opening to the atrium. Bayer used matt finished louver and blind system in the window façade partially covering the lower part and leaving upper part free, preventing glaze on computer screen and allowing unhindered vision from above. This has helped to reduce the lighting requirement considerably.[9]

Figure 2: Bayer Factory daylighting system[10]

(Source: Daylight in building, Solar Heating and Cooling Programme International Energy Agency)

California Energy Commission Public Interest Energy Research Program has designed a guideline for skylight with suspended ceiling for effective utilization of daylight and reduces the overall lighting requirement[11].

Case III - Helsingborg Hospital

Department of Coronary Angiography at Helsingborg Hospital, Sweden brought sunlight into the room through Solar Cables, which could easily pass through complex building structure from the roof, which was far off. The lighting solution were installed on East and West façade so one set of system brought morning sunlight to control rooms and other one brought daylight in at evening time. In case where sun is not out they used artificial lightings.

There are ample cases where daylight has been used effectively to reduce the artificial light requirement.

VI. CHALLENGES OF DAY LIGHT HARVESTING SYSTEM

Daylight being dependent on Sun has a major issue of lack of consistency throughout the day and seasons. These problems will be persistent till the method of storage of daylight will be evolved. Day light fluctuation challenge has been partially answered by supplementing the system with sensors, which activate the artificial light to required level to balance the deficit daylight.

In recent times as the cost of land is rising buildings are coming as vertical structures and the landscape planning are very dense. Although the optimum building orientation for day light harvesting through the openings in construction comply to, the shadow from surrounding building restricts light from entering the building also the challenge faced by researchers is to bring daylight to all story of the building and not just on to top floor or façade side of the building.

Another major issue of daylight is that it is being harvested near the window, open areas and under the roof only. There is no mechanism available to efficiently transfer the light to deep interior regions of building. Thus the major challenge is to design a system that can bring light to deep interiors to building and allow light to be bent at 90^0also keeping under consideration the comfort of occupant in terms of low heat gain in the room and prevent any glare related issues.

VII. CONCLUSION:

Acceptance of skylight harvesting solutions is gaining pace day by day. Various models of skylight harvesting have been demonstrated successfully for industrial lighting and thus the usage of artificial lights has been reduced substantially. These works are based on specific models and find limited usage, due to geographical variations and limited reproducibility. Efforts have been made to replicate it and make it more commercially viable and acceptable. Concurrently challenge of transmitting the daylight into deeper interiors should be met by bending and transmitting light to longer distance.

REFERENCES

[1] India. Central Statistics Office, National Statistical Organisation, Ministry of Statistics and Programme Implementation, Government of India. (2013) Energy Statistics. New Delhi: Central Statistics Office

[2] India. Confederation of Indian Textile Industry. (2013) India's Textiles and Apparel Industry. Mumbai: CITI

[3] Ethical Fashion Forum. (n.d.)Wages & workers' rights.[Online] Available from: http://www.ethicalfashionforum.com/the-issues/wages-workers-rights. [Accessed: 27 Feb 2014]

[4] Magda Havas, M.; Hutchinson, T. (2008) Environmental and Health Concerns Associated with Compact Fluorescent Lights. [Online] June 2008. Available from: http://gogreen-solutions.com/wp-content/uploads/2012/01/Lighting-Heath-Study-Dr.-Magda-Havas.pdf . [Accessed: 23rd Feb 2014]

[5] Magda Havas, M.; Hutchinson, T. (2008) Environmental and Health Concerns Associated with Compact Fluorescent Lights. [Online] June 2008. Available from: http://gogreen-solutions.com/wp-content/uploads/2012/01/Lighting-Heath-Study-Dr.-Magda-Havas.pdf . [Accessed: 23rd Feb 2014

[6] Figueiro, G.; Mark, S.; Richard, G.; and Rea, C. (2002) Daylight and Productivity – A Possible Link to Circadian Regulation.[Online] Available from: http://www.lrc.rpi.edu/programs/lightHealth/pdf/daylightProductivity.pdf. [Accessed: 23rd Feb 2014]

[7] Evans, S. (2009) Towards a sustainable industrial system, with recommendations for education, research, industry and policy.[Online] Available from: http://www.ifm.eng.cam.ac.uk/research/industrial-sustainability/initiatives/sustainable-industrial-systems/. [Accessed: 23rd Feb 2014]

[8] Evans, S. (2009) Towards a sustainable industrial system, with recommendations for education, research, industry and policy.[Online] Available from: http://www.ifm.eng.cam.ac.uk/research/industrial-sustainability/initiatives/sustainable-industrial-systems/. [Accessed: 23rd Feb 2014]

[9] United Kingdom. (2010) Daylight in building, Solar Heating and Cooling Programme International Energy Agency. [Online] Available from: http://www.iea-ebc.org/fileadmin/user_upload/docs/EBC_Annex_29_PSR.pdf. [Accessed: 27th Feb 2014]

[10] United Kingdom. (2010) Daylight in building, Solar Heating and Cooling Programme International Energy Agency. [Online] Available from: http://www.iea-ebc.org/fileadmin/user_upload/docs/EBC_Annex_29_PSR.pdf. [Accessed: 27th Feb 2014]

[11] Boyce, P.; Hunter, C.; Howlett, O.(2013) The Benefits of Daylight through Windows. [Online] September, 2013. Available from: http://www.usp.br/fau/cursos/graduacao/arq_urbanismo/disciplinas/aut0213/Arquivos_Anteriores/Publicacoes_e_Referencias_Eletronicas/The_Benefits_Of_Daylight_Through_Windows.pdf. [Accessed: 25th Feb 2014]

AUTHORS

First Author – Prof. Pavan Godiawala,B.E. Mechanical, M.Sc. Manufacturing Management. Department of Fashion Technology, National Institute of Fashion Technology Gandhinagar,
Email – pavan_15@yahoo.com
Second Author -Prof. Dr. Noopur Anand, M.Sc. Textile and Clothing; PhD; Department of Fashion Technology, National Institute of Fashion Technology New Delhi.
Email – noopur_anand@yahoo.com
Third Author – Dr. Jayantilal Mathurbhai Patel, B.E.-M.E. Mechanical Engineering, PhD. Department of Mechanical Engineering, L. D. College of Engineering;Ahemdabad
Email – jmpatel2098@yahoo.co.in

Corresponding Author –Prof. Pavan Godiawala
Email - pavan_15@yahoo.com, director.gandhinagar@gmail.ac.in
Phone - +91-9824311314