International Journal of Engineering Research-Online
A Peer Reviewed International Journal
Email:editorijoer@gmail.com http://www.ijoer.in

Vol.4., Issue.2., 2016 (Mar-Apr)

REVIEW ARTICLE

ISSN: 2321-7758

A SURVEY ON SOLAR PHOTOVOLTIC SYSTEM

A RENEWABLE ENERGY TECHNIQUE

DEVASHREE JOSHI[1], SWAPNITA DHABRE[2]

[1, 2]Department of Electronics & telecommunication Engineering
VIIT, Pune, India

ABSTRACT

Global environmental disquiets and the rising requirements for energy resources need steady growth in renewable energy conservation technologies. We have ample amount of research opportunities for utilizing renewable energy resources. Solar energy is the best example because it is available easily in abundant form. The solar energy captured on the earth is about $1.8x10^{11}$ MW, which is many times larger than the present rate of all the energy utilization. Solar power can be utilized in the best way using photovoltaic technology. This paper analyses power generating capacity using photovoltaic technology which is developed using different light absorbing materials and its environmental aspect coupled with a variety of its applications. The different existing performance and reliability evaluation models, efficiency have also been discussed.

Keywords—renewable energy; photovoltaic ; solar cells; applications

INTRODUCTION

Presently the world energy consumption is 10TW (Terawatts) and by 2050 it is projected to be about 30TW.The world will need about 20TW non-CO_2 energy to stabilize CO_2 in atmosphere by mid-century[1].

So the world is in need of renewable energy system. To fulfill above requirement different renewable energy techniques are used like wind energy system, photovoltaic system, solar energy system and geothermal system.

Wind power is widely used in Europe, Asia, and the United States which is having installation capacity of 282,482 megawatts (MW) till the end of 2012. Photovoltaic (PV) power stations were very popular in Germany and Italy, having worldwide capacity of 100,000 MW. Solar thermal energy stations operate on 354 MW which are used in the USA and Spain. The world's largest geothermal power installation is The Geysers in California, with a rated capacity of 750 MW. The largest renewable energy programs were adopted by Brazil which involving production of ethanol fuel from sugar cane, and ethanol now provides 18% of the country's automotive fuel. USA also has enough availability of Ethanol fuel [45].

Photovoltaic (PV) system is technically and commercially mature technology which is able to generate and supply electricity using solar energy. PV system convert sunlight directly into electricity and are potentially one of the most useful of the renewable energy technologies.

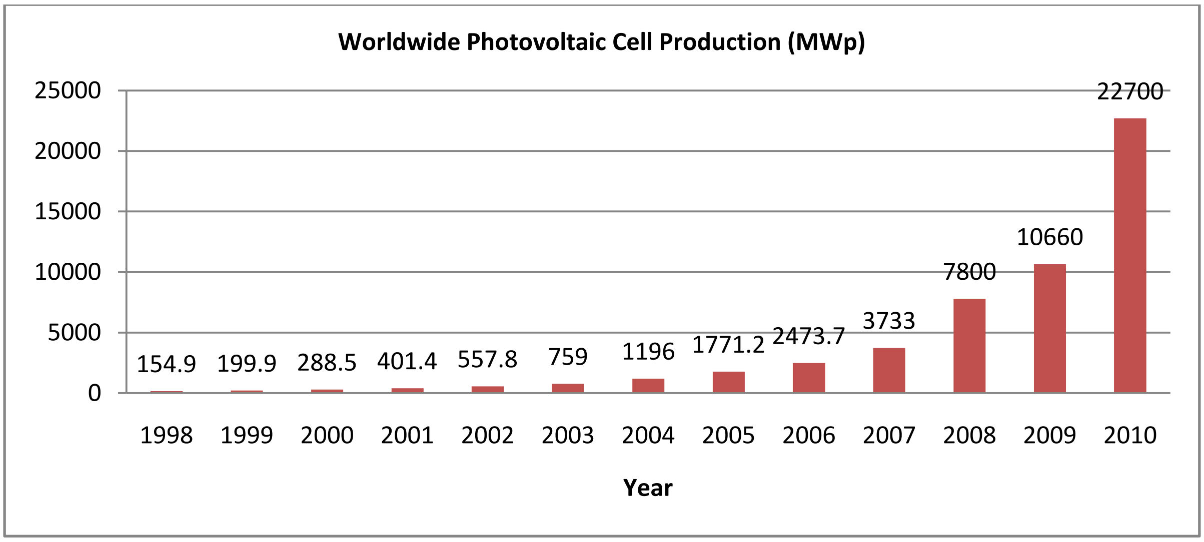
Photovoltaic renewable energy generation

A photovoltaic renewable energy generation system is made up of multiple components like solar cells, mechanical and electrical connections and mountings and means of regulating and/or modifying the electrical output. In clear sunny days these systems produce electrical power from peak kilowatts (kWp) to megawatts [2].

Ito et al. introduced very large scale photovoltaic power generation (VLS-PV) system on desert and designed 100MW PV system and system is installed on the Gobi desert and evaluated parameters like energy payback time (EPT), life- cycle CO_2 emission rate and generation cost of the system were estimated by means of the methodology of life - cycle analysis (LCA)[3]. The parameter energy payback time (EPT) describes the time span a PV system needs to operate in order to generate the same amount of energy that was used for its manufacture and installation. Zhou et. al. estimated economic analysis of power generation from floating solar chimney power plant (FSCPP) by analyzing cash flows during the whole service period of a 100 MW plant [4]. Munner et. al. studied the long term view of large scale PV generation in arid/semi-arid locations, around the globe and its transmission using hydrogen as the energy vector [5].

The recent PV market contains a range of technologies including wafer-based silicon and a variety of thin-film technologies. The range of current technologies and near future options has been explored from current first-generation to future third-generation technologies. [6]

FIGURE I. WORLD PRODUCTION OF PV CELLS



solar cell materials

In photovoltaic system, the solar cell requires light absorbing material to generate free electrons via photo-voltaic effect. This light absorbing material is present in cell structure of the solar cells. Photovoltaic (PV) uses solar cells assembled into solar panels to convert sunlight into electricity. Sunlight, which is pure energy, on striking a PV cell, giving enough energy to some electrons to increase their energy level and make them free. A built-in-potential barrier inside the cell acts on these electrons to generate a voltage, which in turn is used to drive a current through a circuit [2].

First Generation solar cell

The first generation solar cells include Silicon and crystalline silicon. Silicon cells have a very high efficiency, but highly pure silicon is needed. The price of solar cells in this generation is very high as it requires energy processing.

1) Silicon

Braga et al. reviewed the recent advances in chemical and metallurgical routes for photovoltaic (PV) silicon production and found that production of (solar-grade silicon) Sags can be five times more energy efficient than the conventional Siemens process that uses more than 200 kWh/kg [12].Keogh et al. suggested that testing of silicon solar cells under natural sunlight is simpler, cheaper, and more accurate than all but the most careful simulator measurements [13]. Balenzategui et. at focused on the measurement of the angular response of the solar cells based on different silicon technologies and analyzed the sources of deviation from the theoretical response ,especially those due to the surface reflectance[14].

2) Crystalline Silicon

From all other solar cell materials, crystalline silicon based solar cell has the highest efficiency compared to others [15]. Green et al. developed crystalline silicon on glass (CSG) solar cell technology aiming to combine the advantages of standard silicon wafer-based technology with that of thin-films; cost of these contenders is very low and confirmed efficiency for small pilot line modules already in the 8–9% energy conversion efficiency range, on the path to 12–13% [16]. The brief discussion of silicon crystalline materials used in PV cells is given below.

2. a) Mono crystalline silicon cells

Mono crystalline silicon cells have high efficiency up to 20 % but they are costly and cannot be used in commercial world [17]. Vitanov et al. investigated the influence of the emitter thickness on the photovoltaic properties of monocrystalline silicon solar cells with porous silicon [18].

2. b) Polycrystalline silicon cell

Polycrystalline silicon cells have low efficiency in the range of 15% to 17% but they are economical and can be used in commercial world [17]. Barnett et al. investigated that solar cells utilizing thin-film polycrystalline silicon can achieve photovoltaic power conversion efficiencies greater than 19% as a result of light trapping and back surface passivation with optimum silicon thickness [19].

Second Generation solar cell

The next step in the evolution of PV and reduced cost is to remove the unnecessary material from the cost equation by using thin-film devices. Second-generation (2G) technologies are single-junction devices that aim to use less material while maintaining the efficiencies of 1GPV. 2G solar cells use amorphous-Si (a-Si), CdTe/CdS (CdTe) or polycrystalline-Si (p-Si) deposited on low-cost substrates such as glass.

1) Amorphous-Silicon

Amorphous silicon is a non-crystalline form of silicon in disordered structure and has 40 times higher rate of light absorptive compared to mono crystalline silicon [20]. Yang et al. discussed multijunction devices made on lightweight flexible substrates; various aspects of attaining high efficiency devices are described. The eminent role of the roll-to-roll continuous deposition technique in propelling the technology to global market is elucidated [21]. Tyagi analyzed the degradation of three technologies of amorphous silicon which are single junction amorphous silicon, triple junction amorphous silicon and flexible triple junction amorphous silicon and found that each materials degrade by 45%, 22% and 27%, respectively [22]. Aberle reviewed the most promising thin-film c-Si PV technologies that have emerged during the last 10 years and found that three different thin-film c-Si PV technologies (SLIVER, hybrid, CSG) can be transferred to industrial production [23].

2) Cadmium telluride (CdTe) and cadmium sulphide (CdS)

Ferekides et al. presented work carried out on CdTe/CdS solar cells fabricated using the close spaced sublimation (CSS) process that has attractive features for large area applications such as high deposition rates and efficient material utilization [24]. Pfisterer demonstrated the influence of surface treatments of the cells (Cu2S–CdS) and of additional semiconducting or metallic layers of monolayer-range thicknesses at the surface and discussed effects of lattice mismatch on epitaxy as well as wet and drytopotaxy and preconditions for successful application of topotaxy [25]. Richards et al. demonstrated using ray-tracing simulations that the short-wavelength response of cadmium sulfide/cadmium telluride (CdS/CdTe) photovoltaic (PV) modules can be improved by the application of a luminescent downshifting (LDS) layer to the PV module that exhibit a poor internal quantum efficiency [26].

Third Generation solar cell

As 2G technology progressively reduces the active material cost with thinner films, eventually even the low-cost substrate will become the cost limit and higher efficiency will be needed to maintain the cost-reduction trend. The possible future is for third-generation (3G) devices, which exceed the limits of single- junction devices and lead to ultra-high efficiency for the same production costs of 1G/2G PV, driving down the cost[6].The 3G technology devices uses organic and polymer cell and hybrid photovoltaic cell.

1) Organic and polymer cells

Jorgensen et al. presented an understanding of stability/ degradation in organic and polymer solar cell devices and discussed the methods for studying and elucidating degradation and improving the stability by using different active materials, encapsulation, application of getter materials and UVfilters [27]. Bernede et al. studied different cell configurations: two-layer D/A organic solar cells deposited by vacuum evaporation and bulk D/A heterojunction material based on a discontinuous D/A network thin film obtained by spin coating [28]. Wei et al. demonstrated efficient white organic light-emitting device based on exciplex with higher luminance and luminous efficiency and this bi-functional device with electroluminescence (EL) and PV performances is promising to be used as white displays or backlight source in the future as it can be charged by solar energy through additional apparatus free of work and can also be used as an optical sensor to UV light [29]. Yue et al. developed an organic PV device based on triplet complex Re-Phen with power conversion efficiency of 4% which is high compared to the devices based other metal complexes, state increasing the PV efficiency owing to the existence of a charge transfer(CT) absorption [30]. Mozer et al. presented successful strategies towards improved photovoltaic performance using various materials like double-cable polymers, regioregular polymers and lower bandgap energy polymers representing that the bulk hetero junction concept is a viable approach towards developing photovoltaic systems by inexpensive solution-based fabrication technologies [31].

2) Hybrid photovoltaic cell

Itoh et al. conducted electrical output performances of 'democratic module photovoltaic system' consisting of amorphous-, polycrystalline- and crystalline-silicon-based solar cells that reveal significant differences, mainly with respect to seasonal variation and found that the annual output energy generated by amorphous-Si-based solar cell is about 5% higher than that of crystalline-Si-based arrays [32]. Wu et al. proposed a new technique of maximum power point controller, through which the proposed hybrid PV system could adopt amorphous Si solar cell together with crystalline Si solar cell to realize a PV system with higher ratio of performance to cost [33]. Olson et al. fabricated hybrid poly (3-hexylthiophene) P3HT/nanostructured zinc oxide devices using solution-based methods with efficiencies greater than 0.5% [34].

TABLE I. SILICON SOLAR CELL EFFICIENCIES

Device	Efficiency %
Crystalline silicon (c-Si) (wafer)	24.7
Poly crystalline silicon (pc-Si) (wafer)	19.8
Crystalline silicon (c-Si) (thin film)	8.2
Amorphous Silicon (a-Si) (thin film)	13.7

Applications

The increasing efficiency, lowering cost and minimal pollution are the bonus of the photovoltaic systems that have led to a wide range of application.

Building integrated systems

Building integrated photovoltaic's (BIPV) are photovoltaic materials that are used to replace conventional building materials in parts of the building envelope such as the roof, skylights, or facades. They are increasingly being incorporated into the construction of new buildings as a principal or ancillary source of electrical power, although existing buildings may be retrofitted with similar technology. Yoo et al. proposed a building design to have the PV modules shade the building in summer, so as to reduce cooling loads, while at the same time allowing solar energy to enter the building during the heating season to provide daylight and conducted an analysis of the system performance, Evaluation of the system efficiency and the power output [35].

Bakos et al. described the installation, technical characteristics, operation and economic evaluation of a grid-connected building integrated photovoltaic system (BIPV) and the technical and economical factors were examined using a computerized [36].

Space

Solar panels on spacecraft supply power to run the sensors, active heating and cooling, and telemetry, or their power is used for electric propulsion, sometimes called solar-electric propulsion. Girish studied the possibility of night time photovoltaic power generation in planetary bodies like moon using reflected light energy flux from nearby planetary objects based on latest low-intensity low-illumination (LILT) solar cell technology [37].

Solar Home Systems

Bond et al. described current experience and trials in East Timor with solar photovoltaic (PV) technology by introduction of solar home systems (SHS) [38].

Other Applications

Ji et al. presented a novel photovoltaic/thermal solar-assisted heat pump (PV/TSAHP) system, which can generate electricity and heat energy simultaneously and introduced a mathematical model based on the distributed parameter technique for predicting the dynamic system behavior [39].

Problems associated with PV technology

The Photovoltaic technology itself is still expensive because of people are not aware of this technology so it leads to lack of demand. Despite this obvious price disadvantage other obstacles have to be overcome for PV technologies:

1. Low conversion efficiencies only up to 5-18% but may improve with further research and development.

2. Electricity can be generated only during the day period and not during the evening hours when residents are at home so we can say that domestic PV systems do not necessarily deliver power when it is required.

3. Storage cost is high but can be avoided by connection to the mains whereby additional leftovers can be exported to the grid – but the number of new connections the grid could cope with is not clear – assuming it is of a high enough quality.

4. PV electricity is DC, but we require AC supply for appliances so for converting DC to AC we require inverters which increase the cost further.

5. If PV cells get hot, electricity generation falls significantly. Integrated PV arrays need ventilation to cool then at the back, typically natural draught.

Feltrin et al. analyzed several photovoltaic technologies, ranging from silicon to thin films, multi-junction and solar concentrator systems for terawatt level deployment of the existing solar cells, and for each technology, identified improvements and innovations needed for further scale-up[40].

Future Scope

Photovoltaic is one of the fastest growing industries worldwide and in order to maintain this growth rate need for new developments with respect to material use and consumption, device design, reliability and production technologies as well as new concepts to increase the overall efficiency arises. [41]. Feltrin et al. analyzed several photovoltaic technologies, ranging from silicon to thin films, multi-junction and solar concentrator systems for terawatt level deployment of the existing solar cells, and for each technology, identified improvements and innovations needed for further scale-up [42]. Muneer et al. described solar PV

Electricity as the solution of future energy challenges and the modular approach adopted to meet the year 2025 energy demand of six major cities in India: Chennai, Delhi, Jodhpur, Kolkata, Mumbai and Trivandrum, indicates that the suggested solar hydrogen based energy network has the capability of providing the energy requirements [43]. Feltrin et al. analyzed several photovoltaic technologies, ranging from silicon to thin films, multi-junction and solar concentrator systems for terawatt level deployment of the existing solar cells, and for each technology, identified improvements and innovations needed for further scale-up [44].

Conclusion

The installed PV module system greatly helps reducing the carbon dioxide emission in the environment and safe for global warming problems. The Successful deployment of PV cells on building facades or roofs will greatly reduce the need for additional land for electricity generation from new generation stations. Currently, PV market is developing at very high rate of 35-40% per year. Also, with the evolution of the new generations, the new technologies are used making PV cells giving maximum efficiency and making the PV system more commercial in the market. Thus, PV technology is becoming very economical day by day. This paper would be useful for the solar PV system manufactures, academicians, researchers, generating members and decision makers.

References

[1]. T.M. Razykov, C.S. Ferekides, D. Morel, E. Stefanakos, H.S. Ullal,H.M. Upadhyaya, “Solar photovoltaic electricity: Current status and future prospects”, Solar Energy 85 (2011) 1580–1608, ELSEVIER.

[2]. Bhubaneswari Paridaa, S. Iniyanb, Ranko Goicc, “A review of solar photovoltaic technologies”, Renewable and Sustainable Energy Reviews 15 (2011) 1625–1636,ELSEVIER.

[3]. Ito M, Kato K, Sugihara H, Kichimi T, Kichimi J, Kurokawa K. ,“A preliminary study on potential for very largescale photovoltaic power generation (VLSPV) system in the Gobi desert from economic and environmental viewpoints”, Solar Energy Materials & Solar Cells 2003;75:507–17.

[4]. Xinping Zhou, Jiakuan Yang, Fen Wang, Bo Xiao. “Economic analysis of power generation from floating solar chimney power plant”, Renewable and Sustainable Energy Reviews 2009;13:736–49.

[5]. Muneer T, Asif M, Kubie J. , “Generation and transmission prospects for solar electricity: UK and global markets”, Energy Conversion and Management2003;44:35–52.

[6]. Green, M., “Third-Generation Photovoltaics: Advanced Solar Energy Conver- sion”, Springer, Berlin.2006.

[7]. Braga AFB, Moreira SP, Zampieri PR, Bacchin JMG, Mei PR. “New processes for the production of solar-grade polycrystalline silicon: A review,”, Solar Energy Materials & Solar Cells 2008;92:418–24.

[8]. Dobrzanski LA, Drygała A., “Laser processing of multicrystalline silicon for texturization of solar cells”, Journal of Materials Processing Technology 2007;191:228–31.

[9]. Wronski CR, Von Roedern B, Kolodziej A., “Thin-film Si:H-based solar cells”, Vacuum 2008;82:1145–50.

[10]. Macdonald D, McLean K, Deenapanray PNK, DeWolf S, Schmidt J. , “Electronically-coupled up-conversion: an alternative approach to impurity photovoltaics in crystalline silicon”, Semiconductor Science and Technology 2008;23:015001.

[11]. Franklin E, Everett V, Blakers A, Weber K.Sliver, “ solar cells: high-efficiency low-cost PV technology”, Advances in Opto Electronics 2007;

[12]. Braga AFB, Moreira SP, JMG, Mei PR. “New processes for the production of solar-grade polycrystalline silicon: A review”, Solar Energy Materials & Solar Cells 2008;92:418–24 .

[13]. Keogh WM, Blakers AW. , “Accurate measurement using natural sunlight, of silicon solar cells”, Progress in Photovoltaics: Research and Applications 2004;12:1–19.

[14]. Balenzategui JL, Chenlo F., “Measurement and analysis of angular response of solar cells”, Solar Energy Materials & Solar Cells 2005;86:53–83.

[15]. Gorter, T., & Reinders, A. (2012). , “A comparison of 15 polymers for application in photovoltaic modules in PV-powered boats”, Applied Energy, 92, 286-297.

[16]. Green MA, Basore PA, Chang N, Clugston D, Egan R, Evans R, Hogg D, Jarnason S, Keevers M, Lasswell P, Sullivan JO, Schubert U, Turner A,WenhamSR, Young T., “Crystalline silicon on glass (CSG) thin-film solar cell modules.”, Solar Energy 2004;77:857–63.

[17]. Danijela Nikolic, Milorad Bojic,Jasmina Skerlic,Jasna Radulovic, Marko Miletic, " A Review Of Silicon Solar Cells In Photovoltaics Technology",7th International Quality Conference May 24th 2013.

[18]. Vitanov P, Delibasheva M, Goranova E, Peneva M., "The influence of porous silicon coating on silicon solar cells with different emitter thicknesses.", Solar Energy Materials & Solar Cells 2000;61:213–21.

[19]. [19]. Barnett AM, Rand JA, Hall RB, Bisaillon JC, DelleDonne EJ, Feyock BW, Ford DH, Ingram AE, Mauk MG, Yasko JP, Sims PE. High current, thin silicon-on-ceramic solar cell. Solar Energy Materials & Solar Cells 2001;66:45–50.

[20]. Fundamentals of PV material, (1998). Retrieved from: www.sfsu.edu/_ciotola/solar/ pv.pdf

[21]. Yang J, Banerjee A, Guha S. Amorphous silicon based photovoltaic —from earth to the "final frontier". Solar Energy Materials & Solar Cells 2003;78:597–612.

[22]. Tyagi, V.V., Nurul, A. A., Rahim, N. A., Jeyraj, A., & Selvaraj, L. (2013). Progress in solar PV technology: Research and achievement. Renewable and Sustainable Energy Reviews, 20, 443-461.

[23]. Aberle Armin G., " Fabrication and characterization of crystalline silicon thin film materials for solar cells.", Thin Solid Films 2006;511–512:26–34

[24]. Ferekides CS, Marinskiy D, Viswanathan V, Tetali B, Palekis V, Selvaraj P, Morel DL, " High efficiency CSS CdTe solar cells.", Thin Solid Films 2000;361–362:520–6.

[25]. Pfisterer F. , " The wet-topotaxial process of junction formation and surface treatments of Cu S–CdS 2 thin-film solar cells.", Thin Solid Films 2003;431–432:470–6.

[26]. Richards BS, McIntosh KR., " Overcoming the poor short wavelength spectral response of CdS/CdTe photovoltaic modules via luminescence down-shifting: ray-tracing simulations.", Progress in Photovoltaics: Research and Applications 2007;15:27–34.

[27]. Jorgensen M, Norrman K, Krebs FC., " Stability/degradation of polymer solar cells.", Solar Energy Materials & Solar Cells 2008;92:686–714.

[28]. Bernede JC, Derouiche H, Djara V., "Organic photovoltaic devices: influence of the cell configuration on its performances." Solar Energy Materials & Solar Cells 2005;87:261–70.

[29]. Wei H, LiW, Li M, SuW, Xin Q, Niu J, Zhang Z, Hu Z., "White organic electroluminescent device with photovoltaic performances.", Applied Surface Science 2006;252:2204–8.

[30]. Sumei Yue, Bin Li, Di Fan, Ziruo Hong, Wenlian Li. Rhenium, "complex as an electron acceptor in a photovoltaic device.", Journal of Alloys and Compounds 2007;432:L15–7.

[31]. Mozer AJ, Niyazi Serdar Sariciftci., "Conjugated polymer photovoltaic devices and materials.", C R Chimie 2006;9:568–77.

[32]. Itoh M, Takahashi H, Fujii T, Takakura H, Hamakawa Y, Matsumoto Y., " Evaluation of electric energy performance by democratic module PV system field test.", Solar Energy Materials & Solar Cells 2001;67:435–40.

[33]. WuL, TianW,Jiang X., "Silicon-based solar cell system with a hybrid PV module.", Solar Energy Materials & Solar Cells 2005;87:637–45.

[34]. Dana C, Olson, Jorge Piris, Reuben T, Collins, Sean E, Shaheen, David S, Ginley, "Hybrid photovoltaic devices of polymer and ZnO nanofiber composites.", Thin Solid Films 2006;496:26–9.

[35]. Yoo S-H, Lee E-T., "Efficiency characteristic of building integrated photovoltaics as a shading device.", Building and Environment 2002;37:615– 23.

[36]. Bakos GC, Soursos M, Tsagas NF., "Techno economic assessment of a building integrated PV system for electrical energy saving in residential sector", Energy and Buildings 2003;35:757–62.

[37]. Girish , "Nighttime operation of photovoltaic systems in planetary bodies", Solar Energy Materials & Solar Cells 2006;90:825–31.

[38]. Bond M, Fuller RJ, Lu Aye, "A policy proposal for the introduction of solar home systems in East Timor", Energy Policy 2007;35:6535–45.

[39]. Ji J, He H, Chow T, Pei G, He W, Liu K., "Distributed dynamic modeling and experimental study of PV evaporator in a PV/T solar-assisted heat pump", International Journal of Heat and Mass Transfer 2009;52:1365–73.

[40]. Feltrin A, Freundlich A., "Material considerations for terawatt level deployment of photovoltaics", Renewable Energy 2008;33:180–5.

[41]. Jager-Waldau A. European photovoltaics in worldwide comparison. Journal of Non-Crystalline Solids 2006;352:1922–7.

[42]. Feltrin A, Freundlich A. Material considerations for terawatt level deployment of photovoltaics. Renewable Energy 2008;33:180–5.

[43]. Muneer T, Asif M, Munawwar S. Sustainable production of solar electricity with particular reference to the Indian economy. Renewable and Sustainable Energy Reviews 2005;9:444–73.

[44]. Parida, B., Iniyan, S., & Goic, R. (2011). A review of solar photovoltaic technologies, Renewable and Sustainable Energy Reviews, 15, 1625-1636.

[45]. http://en.wikipedia.org/wiki/Photovoltaics