Solar Energy Technology

Sumedha R.G. Weliwaththage, Udara S.P.R. Arachchige

Faculty of Technology, University of Sri Jayewardenepura, Sri Lanka

Abstract – Energy resources can categorize as renewable energy resources and non-, renewable energy resources. Due to some harmful environmental impacts such as air pollution, climate change, and natural resources decay, people are focused on using renewable energy resources to generate energy. Solar energy is one of the widely discussing renewable energy resources. Recently with the rising human population and energy demand, new technologies and improvements should be made in the solar energy field to fulfill the global energy demands and increase energy efficiency. The electricity cannot generate at night is a massive weakness of the traditional solar cell. In this study mainly focus on solar energy and discusses innovation, improvements, and future view of solar energy technologies.

Index Terms – Anti – solar cell, Innovations, rectenna, tandem solar cell.

1 INTRODUCTION

People of the world have to pay attention to renewable energy resources due to the limitation and impact of non-renewable energy resources. Due to global warming, greenhouse gas emissions, fluctuating oil prices, and rising electricity demand in developing countries have to consider new solutions [1]. So renewable energy is affected by the current energy structure and direction of energy development as an essential part. Solar energy is a type of renewable energy resource which has been extensive – scale development and full applications due to energy transmission limitations [2]. Usually, solar energy has many advantages than fossil-based coal and oil due to reduce carbon emissions, clean the air, and can generate again within our lifetimes [3]. In the present scenario of the world, the consumption of electricity has been increased. Therefore researchers have focused on developing solar energy technologies to obtain a high-efficiency level with minimum investment cost and less environmental pollution [3].

When considering solar energy technology, its intermittent and fluctuating characteristics, utilization, and efficiency are limited. For rural and mountainous areas far away from large power grids, generally, solar hybrid power systems are used. Due to randomness and fluctuation of solar power cannot provide continuous and stable active power output [2]. In general, this solar power is not adaptable to everywhere due to the distribution of natural resources are dependently on the culture of the individual community [4]. When considering fossil-based electricity generated systems such as thermal oil power plants and coal power plants, they can generate electricity with maximum power output than the solar energy power plant. Other hands have to pay the high initial cost in solar power generation. When considering the above things, to fulfill the global rising energy demand, researchers have to introduce and buildup innovation in the solar energy field to overcome their disadvantages and challenges.

In 2014, the total global primary energy consumption was about 160310 million MWh, and this value had been projected to be increased to 240318 million MWh in 2040 [5]. In 2010, the renewable energy-based electricity generation system had been raised about 20%, compared with total electricity generation, and it will be about 31% in 2035% [6]. According to the sustainable future scenario of the International Energy Agency, by renewable energy resources, 57% of world electricity supply will be provided by 2025 [6]. A long term forecast and planning is required to achieve the target [7]. Generally, electricity production using solar energy is overgrowing across the world [8]. There are some negative and irreversible externalities in conventional energy production, and therefore solar energy supply technologies should be promoted and developed [9]. During recent years a large amount of investment has been made, and the advancement of technology has enabled countries to produce solar energy more cost-effectively [9].

Researchers are contributing to tremendous innovation in the solar energy field for obtaining high efficiency with less environmental pollution. In the solar energy field, due to the cost of extracting and manufacturing processes, the use of crystalline silicon for fabricating solar cells can be expensive. So, in the future organic materials will be added as new materials for building solar cells [5]. Due to the lower production cost and environmental friendliness, the use of organic materials for solar photovoltaic cells has some benefits [5]. According to the traditional solar cell, without solar radiation, electricity cannot be generated. However, near future, under the anti-solar cell concept, the electricity will be generated at night without sunlight [10]. So, mainly in this review paper, briefly discuss the innovation and future of solar energy technology.

2 THE WEAKNESS OF THE SOLAR ENERGY TECHNOLOGIES

Nowadays, most of the solar cells have been made using silicon materials [11]. The fabrication procedure of traditional C-Si solar cells can be mentioned below.

- Wafer cleaning and saw damage removal
- Surface texturing
- Doping of textured wafer for junction formation
- Antireflection coating and font surface passivation
- Metallization
- Edge isolation

High purify silicon ingots extracts from the silica to start the production of the solar cells [12]. Solar energy is available only in the day time. Due to that reason, only when there is sunlight can the photovoltaic panels and other collectors convert sunlight into other forms of energy. For this reason, a new energy storage system is required to get an uninterrupted power supply. This backup system is also an additional cost that makes the solar system more expensive [12].

In the traditional silicon solar cell, all the wavelength parts of the solar spectrum will not be absorbed by solar cells. They have absorbed only some parts of the solar spectrum. Other parts are wasted. When comparing with other energy conversion systems, the conversion efficiency of solar cells is very low, which is around 20% in general [12].

For larger applications, many photovoltaic cells are needed to absorb enough energy. Due to the overheating of the panel, the efficiency of the photovoltaic panel drops dramatically, and therefore large quantities of the solar panel are required. There is a large space required for solar collectors. This situation is a challenging task when considering other purposes of space required [13].

The solar energy can be harnessed most efficiently only when it is sunny. The regions with unsustainable weather or climate conditions, solar energy are not the most reliable source. The effectiveness of the solar cells strongly depends on the level of air pollution. The exhaust fumes and aerosols have minimized the current of silicon solar cells by 10% and 7% [14].

3 THE INNOVATIONS OF SOLAR ENERGY TECHNOLOGY

According to the traditional solar cell, electrical power cannot generate after the sunset. Under the anti-solar cell concept, electricity can be generated using solar cells at night [15]. According to the anti-solar cell concept, the earth is considered a heat source, and the night sky considers radiative photovoltaic and concepts from the advanced radiative cooling field. The physical principles of thermo-radiative cells are similar to conventional photovoltaic. When happening the thermal equilibrium of a p – n junction with its surroundings in the dark, the random absorption of photons by the cell equals the random emission from the cell, and the Fermi level remains at the constant level through the semiconductor. When the p – n junction is at a higher temperature than its surroundings, emission from that device dominates absorption as the device tries to cool. The cell temperature remains constant when the cell is connected with a thermal reservoir. Due to that case, the enhanced emission minimizes the carrier concentration below its equilibrium value, which splits the hole and electron Fermi levels in the opposite direction and generates a reverse bias voltage across the junction. The recombination of a hole and an electron and hole pair that is not balanced by absorption of photon results in an additional electron and hole being inserted via the contacts to equal the lost pair. When a cell is connected to a load, this situation results in a current flow [16]. The main difference between a thermo-radiative PV cell and conventional PV cell is,

- The current flows in the opposite direction.
- The sign of the generated voltage is also reversed.

Fig. 1 shows the anti-solar cell concept.

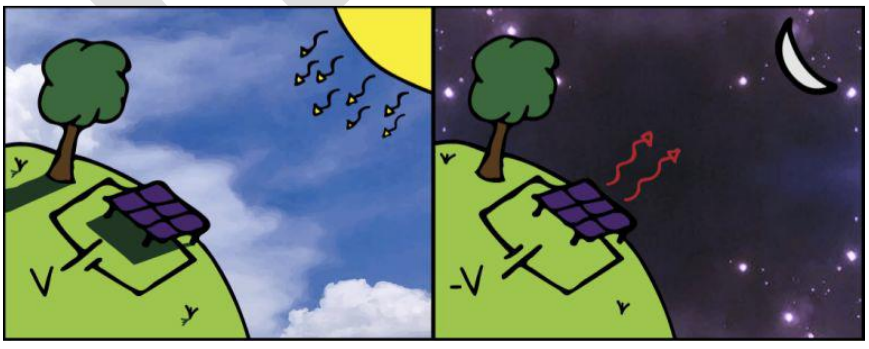

Fig. 1. Anti – solar cell concept [16]

The optical rectenna concept has been proposed as an alternative to conventional semiconductor photovoltaic. A rectenna is a high - frequency rectifier system, including an antenna that receives electromagnetic radiation and a diode that converts it to DC power. The infrared sensing and detection are the main applications of rectenna. The harvesting of solar energy using optical frequency rectenna is a potentially low–cost route to high-efficiency Photovoltaics. As well as the materials are inexpensive and not limited in availability, and the fabrication is suited to roll – to – roll manufacturing. When talking about semiconductor solar cells that are fundamentally limited in the minimum frequency of radiation that can be harvested is proportional to the band gap. A rectenna's frequency response is dependent primarily on the creation of the antenna, and its impedance match with the diode [17]. Under this rectenna concept, it can achieve efficiencies up to 100% under monochromatic illumination [18].

The concentrated photovoltaic technology (CPV) is new in solar power technology. In this technology, mirrors, and lenses used to focus the sunlight on solar cells for generating electricity. CPV has an advantage over non concentrated photovoltaic. The lower number of solar cells is required for the same power output is one of them. The intensity of sunlight and temperature are greatly affected by the performance of the solar cell. At the high temperature, the output performance of the solar panel reduces as compared with lower temperatures. According to the previous case study, under concentrated solar radiation, the performance of the solar cell reduces 50%, when its temperature rises from 46°C to 84°C [19]. Therefore, to get the maximum solar cell's efficiency and to prevent the cell from degradation and damage, an efficient cooling system is quite essential. The photovoltaic solar panel can be cooled by using actively or passively method. In the active mode, some external power source is needed to cool the system and but in a passive way; there is no additional power source [19]. Table 1 shows the performance of the active cooling system solar panel under different concentration techniques.

Table 1. The change in current, voltage and power with respect to concentration and cooling [19]

Voltage	Current	Power	Concentration
12.98	1.91	24.84	Without
15.02	1.92	28.838	1 mirror
15.43	1.93	29.625	Plus cooling
16.11	1.94	31.253	2 mirrors
16.50	1.94	32.011	Plus cooling
16.71	1.95	36.929	3 mirrors
16.91	2.23	37.709	Plus cooling

When talking about the cooling system of solar panels, a micro-heat-pipe arrays system is proposed to dissipate heat from the operating temperature of solar cells. This proposed method can solve the problem of low energy output efficiency and thermal failure due to high solar cell temperature [20]. Solar energy is currently widely used in various fields because it has unlimited reserves; it is universality, clean, and has many other advantages. The efficiency of the solar cell is an essential thing. So below, several important ways are proposed to improve the efficiency of solar power [21].

- Improving the conversion efficiency of solar panel – Solar panel is the main component for converting solar energy into electricity. In recent years, scientists are developing researches to invent new solar panels. The Nano solar panel demonstrates a new development side as the latest achievement of solar panels in recent years.
- The automatic tracking system – Solar light and solar panel are vertical. The generating capacity of the solar cell will change with time due to the sunlight is in a changing perspective. By using adopting automatic tracking system can increase the generating capacity [22]. Fig. 2 shows a simple automatic tracking solar system model.

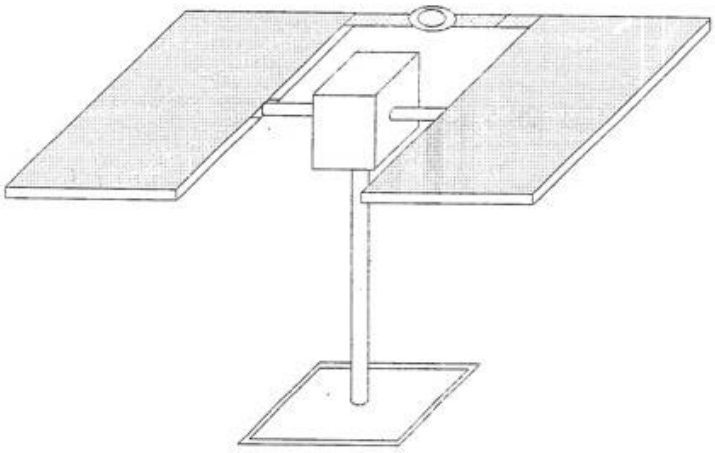

Fig. 2. The simple automatic tracking solar system model [22].

- Separate the collection and transformation part into two independent devices – The collector is one of them, and it is the serial collection and to strengthen solar energy. The converter is another one, and it converts the light energy into electrical energy. This collector is made by using mirrors. The converter converts the thermal energy into electrical energy and, so the generating capacity is increased a thousand times the general solar panel.

The solar cell is an electronic device that converts the sunlight into electrical energy by flowing electrons between two layers of semiconductors. The panel surface wants to be dust-free and in the absence of any kind particles which obstruct the flow of photons. Then solar cell operates at optimum efficiency without any loss of energy. To extract maximum output, consumers need to keep the panels and thus arrays clean with the help of a highly controlled process. Some water is used for the cleaning because most

commercial crystalline silicon photovoltaic cells observe a suitable current-voltage characteristic at lower temperatures. An automation system is mostly required for this cleaning process, and it is a better solution than a manual one [22]. Fig. 3 shows a cost-effective automation system for a hugely optimized cleaning of solar panel arrays.

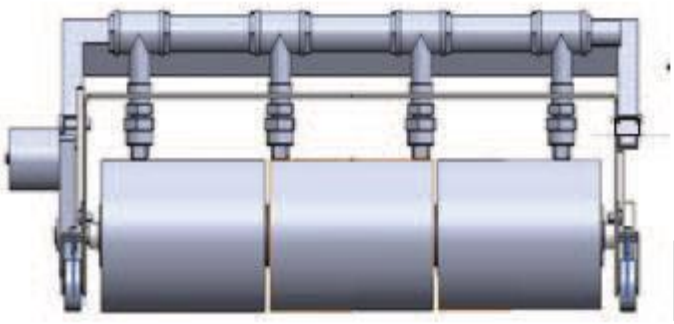

Fig. 3. The automation system for cleaning the solar panel [22]

When talking about the generation of the solar cell, the thin film is a second-generation solar cell. Cadmium telluride (CdTe), copper indium gallium diselenide (CIGS) are some second generation materials. This thin-film solar cell is flexible, becoming popular with acceptable efficiency and excellent performance [23]. The multi-junction solar cell is a type of thin-film solar cell, and it has made by consisting of two or more sub cells together. The traditional solar cell converts some part of the sunlight spectrum into electricity, but in the tandem solar cells, the more the sunlight is converted into electricity. Therefore increases the overall cell efficiency.

The solar tree concept is the best innovation idea in solar cell technology. Because today, the human population is rising rapidly and, therefore, cannot find enough space to install the solar panel. However, this solar tree is required a very less space to produce efficiently. Thus the solar tree could be the best one for today's world. When comparing with the traditional system, in the conventional method, we require a massive amount of land to generate a small capacity of power—this artificial tree with photovoltaic cells arranged in a Fibonacci series manner in place of leaves. When considering with trees, green leaves are producing food materials for organisms; likewise, this solar tree leaves are producing energy for society [24]. Fig. 4 shows the artificial solar tree.

Fig. 4. The artificial solar tree [24]

According to the environmental conditions of Medellin in Colombia, a solar unit tree was designed to talk about the solar tree PV system. This is about 3.5m height tree, and it has four leaves made of acrylic with solar panels on the top. The energy storage capacity of this tree is about 180 Amp, and it has 6 USB ports to connect mobile devices and two 110v – 200W electrical outlets to connect those devices to the electricity [25], [26], [27].

Solar energy is one of the best options to meet future energy demand. Researchers have measured successfully in Detail, the flow of solar energy in and between different parts of a photosynthetic organism for the first time. This result can develop to get high-efficiency solar energy technology than what is currently possible. Researchers have spotted that the device can absorb the sun's broad spectrum radiation and convert it to electricity by using a heat – resistant device, made of tungsten and alumina layers. For fabricating the dye-sensitized solar cells, a green polymer derived from bio waste was applied [28].

4 DISCUSSION

Conventional energy sources based on oil, natural gas, and coal are the highly effective drivers of the economic process. Worldwide primary energy consumption grew by 1.8% in 2012, with the rapid depletion of conventional energy sources and increasing energy demand. Many organizations have encouraged intensive research for more efficient and green power plants utilizing advanced technology [29].

When considering solar energy technology, the main problem is that it has a lower efficiency than nonrenewable technology when generating electricity. It can create maximum electricity capacity by using a nuclear power plant and fossil-based power plant than a solar power plant. Therefore overcome this challenge, obtain maximum efficiency, and fulfill the future energy demand, should be done innovation and researches in the solar energy sector. This is not a simple way. Researchers have to pay a high initial cost for doing investigations and have to study advanced technology. However, by doing innovations and researches in the solar energy field, our planet can change as a better place for living by decreasing the environmental impacts involved with non – renewable technologies.

Solar power technology is developing for the second and third generations. More researches have been done with nanomaterial for using them into solar technology. By using the traditional silicon-based solar panel only can extract some parts of the solar spectrum. However, by using a multi-junction solar cell, can extract all the part of the solar spectrum and then can improve the efficiency of the solar cell. By using hybrid solar power technology, such as solar – wind system and solar – biomass technology can generate electricity during the cloudy days and at night time. Due to applying innovations in solar technology below benefits can get.

- By extracting many parts of the solar spectrum, can get maximum efficiency
- Reduce the initial cost
- Can get a flexible solar cell and fewer environment impacts
- Can generate electricity during the day
- Can generate electricity very efficiently by using concentrated solar technology in the high-temperature regions than traditional solar technology

Before encountering some interrelated incidents which result in the global tragedy of a measure that has never been experienced in human social history, it is understood that we need to substitute our current reliance on fossil fuels. However, there are some disadvantages to solar energy sources. Solar energy technologies are incapable of providing adequate energy to sustain the gradually increasing global energy needs while reducing the effects on the health and environment before on the current finding [30]. The innovation and improvements are needed to overcome the situations mentioned above and to get higher efficiency, similar to nonrenewable technologies such as nuclear power and fossil-based power. So, this paper has discussed the weakness of current solar energy technologies and innovations and future trends of solar power for understanding the future tendency and future direction of the solar energy field.

5 CONCLUSION

The traditional power generation based on solar energy is generally considered to be unsustainable in the long term, due to the inability cases and low power efficiency. As a result, more innovations are introducing all over the world. The electricity generation at night is the most critical innovative options. Based on the current technology, solar energy technologies are in a cable to provide adequate energy to rising energy needs, and when comparing with the nonrenewable technologies. So, innovations are an essential factor in the solar energy sector to develop it with maximum efficiency. So, this paper presents innovative ideas and future views of solar energy technology. As a final word, innovation is a panacea for solar energy technology for full filling the future rising energy demand effectively.

REFERENCES

[1] O. Peter, C. Mbohwa, Renewable energy technologies in brief, Renewable energy technologies in briefInternational Journal of Scientific and Technology Research, Vol.8, 1283-1289, 2019.

[2] Thomas B. McKee, Nolan J. Doeskenand John Kleist, Analysis of Standardized Precipitation Index (SPI) data for drought assessment, Water (Switzerland), Vol.26, 1-72, 1993.

[3] H. Soonmin, S. Wagh, A. Kadier, I. A. Gondal, N. Putra Bin Abdul Azim, M. K. Mishra, Renewable energy technologies, Sustainable Innovation and Impact, 237 – 250, 2018.

[4] J. Mohtasham**,** Review Article-Renewable Energies, Energy Procedia, Vol. 74, 1289-1297, 2015.

[5] Thomas T.D. Tran, Amanda D. Smith, Evaluation of renewable energy technologies and their potential for technical integration and cost-effective use within the U.S. energy sector, Renewable and Sustainable Energy Reviews, Vol.80, 1372-1388, 2017.

[6] M. A. Islam, M. Hasanuzzaman, N. A. Rahim, A. Nahar, andM. Hosenuzzaman, Global renewable energy-based electricity generation and smart grid system for energy security, Scientific World Journal, Vol.2014, 2014.

[7] D. NchelatebeNkwetta, M. Smyth, A. Zacharopoulos, Trevor Hyde, Optical evaluation and analysis of an internal low-concentrated evacuated tube heat pipe solar collector for powering solar air-conditioning systems, Renewable Energy, Vol.39, 65-70, 2012.

[8] F.R. Pazheri , M.F. Othman , N.H. Malik, A review on global renewable electricity scenario, Renewable and Sustainable Energy Reviews, Vol.31, 835-845, 2014.

[9] S. Abolhosseini, A. Heshmati, J. Altmann**,** A review of renewable energy supply and energy efficiency technologies, IZA Discussion Paper Series, 1-36, 2014.

[10] Ronald J. Parise, G. F. Jones, Energy from deep space the Nighttime Solar Cell™ electrical energy production, 35th Intersociety Energy Conversion Engineering Conference and Exhibit, 139-147, 2000.

[11] S. Mughal, Y. Raj Sood, R.K Jarial, A Review on Solar Photovoltaic Technology and Future Trends,NCRACIT) International Journal of Scientific Research in Computer Science, Engineering and Information Technology © 2018 IJSRCSEIT, Vol.1, 227-235, 2008.
[12] F. M. Guangul, Girma T. Chala, Solar energy as renewable energy source: SWOT analysis, 2019 4th MEC International Conference on Big Data and Smart City, ICBDSC 2019, 2019.
[13] K.A. Moharram , M.S. Abd-Elhady , H.A. Kandil , H. El-Sherif, Enhancing the performance of photovoltaic panels by water cooling, Ain Shams Engineering Journal, Vol.4, 869-877,2013.
[14] E. Kabir, P. Kumar, S. Kumar, Adedeji A. Adelodun, Ki-Hyun Kim,Solar energy: Potential and future prospects, Renewable and Sustainable Energy Reviews, Vol.82, 894-900, 2018.
[15]T.E. Girish, Nighttime operation of photovoltaic systems in planetary bodies, Solar Energy Materials and Solar Cells, Vol.90, 825-831, 2006.
[16] T. Deppe, and Jeremy N Munday, Nighttime Photovoltaic Cells: Electrical Power Generation by Optically Coupling with Deep Space, ACS Photonics, Vol.7, 1-9,2020.
[17] Sachit Grover, Saumil Joshi and Garret Moddel, Quantum theory of operation for rectenna solar cells, Journal of Physics D: Applied Physics, Vol.46, 2013.
[18] Saumil Joshi, Sachit Grover, and Garret Moddel, Efficiency limits of rectenna solar cells: Theory of broadband photon-assisted tunneling, Applied Physics Letters, Vol.102, 2013.
[19] Rizwan Arshad, Salman Tariq, Muhammad UmairNiaz, Mohsin Jamil, Improvement in solar panel efficiency using solar concentration by simple mirrors and by cooling, 2014 International Conference on Robotics and Emerging Allied Technologies in Engineering, iCREATE 2014 – Proceedings, 292-295, 2014.
[20] BanchaSreewirote, AkeratanaNoppakant, and ChaichanPothisarn, Increasing efficiency of an electricity production system from solar energy with a method of reducing solar panel temperature, Proceedings of the 2017 IEEE International Conference on Applied System Innovation: Applied System Innovation for Modern Technology, ICASI 2017, 1308-1311, 2017.
[21] DAI Qinghui, CHEN Jun, Improving the efficiency of solar photovoltaic power generation in several important ways, IET Conference Publications, Vol.2009, 2009.
[22] Prof. J. B. Jawale, Prof. V. K. Karra, Dr. B. P. Patil, Puneet Singh, ShailenderSingh,SaloniAtre, Solar panel cleaning bot for enhancement of efficiency - An innovative approach, Proceedings of the 3rd International Conference on Devices, Circuits and Systems, ICDCS 2016, 103-108, 2016.
[23] Imran Ahmad Quadri, ShivanshuRastogi, ShreyankDwivedi and Md. Sarwar, Innovative approach for power and voltage improvement of flexible solar panel, 1st IEEE International Conference on Power Electronics, Intelligent Control and Energy Systems, ICPEICES 2016, 1-4, 2017.
[24] V. Renugadevi, An approach to solar power tree, Proceedings - 2017 IEEE International Conference on Electrical, Instrumentation and Communication Engineering, ICEICE 2017, Vol. 2017-Decem, 1-3, 2017.
[25] E.Duque, A. Isaza, P. Ortiz, S. Chica and A. Lujan, J. Molina, Urban sets innovation: Design of a solar tree PV system for charging mobile devices in Medellin – Colombia, 2017 6th International Conference on Renewable Energy Research and Applications, ICRERA 2017, Vol.2017 January, 495-498, 2017.
[26] FarhanHyder, K. Sudhakar, RizalmanMamat, Solar PV tree design: A review, Renewable and Sustainable Energy Reviews,Vol.82, 1079-1096, 2018.
[27] V. Avdic, A. Muminovic, N. Pervan, P. Tasic, S. Zecevic, Implementation of the Project "Solar tree" in Sarajevo, Green Design Conference, 8-12, 2013.
[28] EhsanulKabir, Pawan Kumar, Sandeep Kumar, Adedeji A. Adelodun, Ki-Hyun Kim, Solar energy: Potential and future prospects, Renewable and Sustainable Energy Reviews, Vol.82, 894-900, 2018.
[29] Omar Ellabban ,HaithamAbu-Rub , FredeBlaabjerg, Renewable energy resources: Current status, future prospects and their enabling technology, Renewable and Sustainable Energy Reviews, Vol.39, 748-764, 2014. [30] Abbas Azarpour, SuardiSuhaimi, GholamrezaZahedi, AlirezaBahadori, A review on the drawbacks of renewable energy as a promising energy source of the future, Arabian Journal for Science and Engineering, Vol.38, 317-328, 2013.