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EDUCATION

- **Doctor of Philosophy**, Indian Institute of Technology Guwahati, India, 2016-2020,
  Thesis title: Development of an efficient photovoltaic thermal collector.
- **Master of Technology in Energy Technology**, Tezpur University, India, 2013-2015, **CGPA:** 9.01/10.
- **Bachelor of Technology in Mechanical Engineering**, Dibrugarh University, India, 2009-2013,
  CGPA: 8.33/10
- Senior School Certificate Examination (12th), Jawahar Navodaya Vidyalaya Morigaon, India, 2009,
  Percentage: 78.8%.
- Secondary School Examination (10th), Jawahar Navodaya Vidyalaya Morigaon, India, 2009,
  Percentage: 89.2%.

RESEARCH INTERESTS

Thermal management in energy systems, Photovoltaic-thermal solar collectors, Form-stable phase change material for thermal energy storage, Photovoltaic system design, Solar distillation, Solar drying

RESEARCH EXPERIENCE

Project Engineer, Nov 2020- till present.

Dept. of Civil Engg., IIT Guwahati

Project title: Implementation of the AICTE funded Solar Photovoltaic and Water projects in the AICTE approved institutes of the North-East region of lndia

Assistant Project Engineer, Sept- Dec, 2015

Dept. of Mechanical Engg., IIT Guwahati

Project title: Thermodynamic Management of PV/Thermal System

PhD Researcher, Jan 2016 – Dec 2020

- Developed an outdoor solar PV- thermal collector testing facility.
- Developed a low-cost solar simulator for Photovoltaic-thermal collector testing.
- Used material characterization tools FESEM, FTIR, XRD, DSC, TGA, BET etc.

Master Researcher, June 2014- June 2015

- Developed a high yield solar still.
- Developed solar still test setup.
- Analyzed data using Origin.

TEACHING EXPERIENCE

Teaching Assistant,

Subjects: Solar Energy Conversion Technology, Renewable Energy Systems and Fundamental of Energy Engineering

Faculty-Incharge: Dr. Pankaj Kalita, Asst. Prof., Centre for Energy, IIT Guwahati

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🕮 PUBLICATIONS

Journals

1. **Das, D.,** Bordoloi, U., Muigai, H., Kamble, A.D., Pai, R.K., Kalita, P. Performance investigation of a rectangular spiral flow PV/T collector with a novel form stable composite material, ***Applied Thermal Engineering,*** 182, 116035, 2021 **(IF: 5.295)**
2. **Das, D.,** Kamble, A.D., Kalita, P. Performance investigation of transparent photovoltaic-thermal collector with horizontal oscillating and rectangular spiral flow patterns, ***International Journal of Energy Research,*** 2020 **(IF: 5.164)**
3. **Das, D.,** Bordoloi, U., Muigai, H., Kalita, P. A novel form stable PCM based bio composite material for solar thermal energy storage applications, ***Journal of Energy Storage***, 30, 101403, 2020. **(IF: 6.583)**
4. **Das, D.,** Kalita, P., Dewan, A., Tanweer, S. Development of a novel thermal model for a PV/T collector and its experimental analysis, ***Solar Energy***, 188, 631-643, 2019 **(IF: 5.742)**
5. **Das, D.,** Kalita, P., Roy, O. Flat plate hybrid photovoltaic- thermal (PV/T) system: A review on design and development, ***Renewable and Sustainable Energy Reviews***, 84, 111-130, 2018. **(IF: 14.982)**
6. **Das, D.,** Kalita, P. Experimental analysis of photovoltaic-thermal collectors with closely spaced tubes,

***Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*, (IF: 3.447)**.

7. **Das, D.,** Bordoloi, U., Kalita, P., Boehm, R., Kamble, A.D. Solar still distillate enhancement techniques and recent developments, ***Groundwater for Sustainable Development,*** 10, 100360, 2020.
8. Kalita, P., Das, S., **Das, D.,** Bor Gohain, P., Dewan, A., Banik, R.K. Feasibility study of MW level grid connected solar photovoltaic power plant installation for northeastern region of India, ***Sadhana,*** 44,9,1-24, 2019. **(IF: 1.188)**
9. Kalita, P., Borah, S., **Das, D.** Design and performance evaluation of a novel solar distillation unit, ***Desalination,*** 416, 65–75, 2017. **(IF: 9.501)**
10. Deka, T.J., Kalita, P., Das, S., **Das, D.,** Kakati, R. Design, development and performance evaluation of a fluidized bed paddy dryer, ***Journal of Energy and Environmental Sustainability***, 6, 2018, 18-23.

Book chapters

1. Kalita P., **Das D.,** Das S., Banik R.K., Bordoloi U. (2021) Heat Transfer Analysis in Solar Thermal Collectors, ***Advances in Sustainable Energy***, 251-277, 2021.
2. **Das, D.,** Kalita, P. Performance improvement of a novel flat plate photovoltaic thermal (PV/T) system using copper oxide nanoparticle- water as coolant, ***Nanotechnology for Energy and Water, Springer Proceedings in Energy,*** 97-104, 2018.
3. **Das, D.,** Kalita, P. Feasibility Study of Photovoltaic-Thermal (PV/T), Collector in Assam (India) Using Polysun, ***Advances in Mechanical Engineering, Springer***, 1331-1337, 2020.
4. Kalita, P., Banik, R.K., Das, S., **Das, D.** An Approach towards Sustainable Energy Education in India, ***Proceedings of the 7th International Conference on Advances in Energy Research***, Springer, 2020.

Conferences

1. **Das, D.,** Kalita, P., Kamble, A.D. Experimental study and performance evaluation of PV/T's with novel absorber designs, ***International Conference on Sustainable Energy and Green Technology 2019 (SEGT 2019),*** Bangkok, Thailand, 11-14 December, 2019.
2. **Das, D.,** Kalita, P. Experimental evaluation of tube PV/T collector, ***12th International Conference on Sustainable Energy & Environmental Protection (SEEP 2019),*** University of Sharjah, UAE, 18 - 21 August, 2019.
3. **Das, D.,** Kalita, P., Experimental evaluation of a rectangular spiral tube only PV/T collector, ***International Conference on Future Aspects of Sustainable Technology (FAST 2019),*** Central Institute of Kokrajhar, 11-12 November 2019.

4. **Das, D.,** Kalita, P. Development of a tube and sheet type PV/T collector: Experimental study and performance evaluation**,** ***National Conference on Waste to Energy 2018***, National Institute of Technology Mizoram, 28-29 December 2018.

AWARDS AND ACHIEVEMENTS

1. **Best Thesis Award**, School of Energy Science and Engineering Indian Institute of Technology Guwahati, 2021.
2. **Best paper award,** ***International Conference on Sustainable Energy and Green Technology 2019 (SEGT 2019)*****,** Bangkok, Thailand, 11-14 December, 2019.
3. ***Bhaskara Advanced Solar Energy (BASE) Internship*** at University of Nevada, USA, sponsored by Dept. of Science and Technology, Govt. of India (DST) and Indo-US Science and Technology Forum (IUSSTF), 2019.
4. **Best Poster Award** at ***Research Conclave 2017***, IIT Guwahati.
5. **Oil and Natural Gas Commission (ONGC)** merit scholarship 2015.
6. Qualified **GATE** in the year **2014** and **2015**.

POSITIONS AND RESPONSIBLITIES

- ✓ Member of Public Relation Team, Research Conclave 2017, IIT Guwahati.
- ✓ Member of Tezpur University Students Council, 2013.
- ✓ Training and Placement Coordinator, Department of Energy, Tezpur University, 2014-2015.
- ✓ Training and Placement Coordinator, Department of Mechanical Engineering, Dibrugarh University Institute of Engineering and Technology, 2011-2013.

SKILLS AND SOFTWARE PACKAGES

Language:

- English – Full professional proficiency
- Hindi – Native or bilingual proficiency
- Assamese – Native or bilingual proficiency

Software packages:

- PVsyst
- TRNSYS
- PolySun
- System Advisor Model (SAM)

PEER REVIEW SERVICES

- ✓ Solar Energy, Elsevier
- ✓ Renewable and Sustainable Energy Reviews, Elsevier.
- ✓ Renewable Energy, Elsevier
- ✓ International Journal of Ambient Energy, Taylor and Francis.

REFERENCES

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Performance investigation of a rectangular spiral flow PV/T collector with a novel form-stable composite material

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ARTICLE INFO

Keywords:
Rectangular spiral absorber
PCM-biochar composite
Form stability
PV/T
Electrical output
Exergy efficiency

ABSTRACT

The electrical output of the Photovoltaic (PV) cells decreases with the increase in the operating temperature. To address the issue of electrical power drop in PV, a new hybrid collector called photovoltaic-thermal (PV/T) module has been proposed by the researchers. PV/T combines a PV and thermal absorber; it helps in cooling of PV and to harness the waste heat from PV for utilizing in low-temperature applications. However, the cooling uniformity and thermal efficiency remain to be major challenges for the broader applicability of PV/T. In this work, a novel rectangular spiral tube only absorber is developed with a transparent multi-crystalline PV module with absorber tubes directly glued to the PV backside. A novel form-stable composite developed by simple impregnation method using PCM (OM35) and biochar derived from water hyacinth. This novel composite is embedded in the enclosure formed by the PV and back cover to improve cooling uniformity and better absorption of incoming radiation due to the blackish appearance of the composite. In the composite, 5% by wt aluminium metal powder is added. The thermal conductivity of the composite is found to improve by 1.66 times than that of pure PCM, while aluminium metal powder is added. The heat of fusion is calculated to be 78 J/g. The developed PV/T system has been experimentally evaluated under outdoor conditions. The average electrical, thermal, energy and exergy efficiency of the PV/T system with novel form-stable thermal energy storage material is reported to be 13 ± 5.04%, 66.6 ± 5.48%, 79.6 ± 5.53%, and 15 ± 5.58% respectively, whereas the average electrical efficiency PV during the experiment found to be 10.7 ± 5.04%. The electrical efficiency of the PV module used is 14.64% under Standard Test Conditions. There is an improvement of 18.4% in electrical output as compared to PV with this novel arrangement.

1. Introduction

The rise of PV system installations across the world due to growing concerns for climate change and energy security has attracted the attention of researchers to develop these systems. Infra-red radiations absorbed by PV becomes heat and reduces the electrical conversion efficiency of the PV cells [1]. The passively cooled PV system, when compared with a bare PV system of same dimensions can yield approximately 5% more power output [2]. PV/T system is a combination of PV and solar thermal systems in which heat generated in the PV is extracted by flowing fluid. This by-product is utilized for various low-temperature applications. Thermal energy produced by a PV/T system can be useful to meet the demand for domestic heating and cooling load. PV/T collector has a thermal efficiency of about 9% lower than the efficiency of the conventional flat plate solar thermal collector [3].

Water-based PV/T collectors have been widely researched across the globe [1]. PV/T collectors used hot water generation has either tube-sheet or only tube type absorbers. The efficiency of PV/T collectors is mainly influenced by the fluid flow pattern [4]. Das et al. [5] reported that the sheet-tube absorber could increase the thermal resistance to the thermal energy flow from the PV layer to the fluid stream in the tubes. Thus, reduces the thermal efficiency of the PV/T collector. The researchers have also recommended that for the effective operation of the PV/T system in summer, continuous removal of heat from the PV/T modules is necessary, especially when the consumption of thermal energy is low [6]. Wu et al. [7] developed a 3D numerical model of water-based PV/T system having cooling channel above the PV panel. The

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A novel form stable PCM based bio composite material for solar thermal energy storage applications

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ARTICLE INFO

Keywords:
Solar energy
Thermal energy storage
Phase change material
Form stability
Water hyacinth biochar
Thermal conductivity

ABSTRACT

Phase change materials found to be a promising solution in the field of thermal energy storage. However, the low thermal conductivity and form stability over cycles of charging and discharging of PCM are challenges to address. In the proposed study, a novel and low cost biochar-PCM hybrid latent heat energy storage material have been developed and tested. The biochar is prepared from aquatic invasive weed plants by using a batch type pyrolyser. The characteristics and properties of the novel energy storage material have been evaluated using various experimental and analytical methods. The methods include Brunauer, Emmett and Teller (BET), Scanning electron microscope (SEM), X-ray powder diffraction (XRD), Differential Scanning Calorimetry (DSC), Thermogravimetric analysis (TGA), Fourier-transform infrared spectroscopy (FT–IR) and thermal conductivity tester. The study also put forward the optimized proportion of biochar and PCM in hybrid thermal energy storage material. The new material shows superior thermal conductivity over pure PCM as well as better stability due to the high carbon content and porosity of the developed biochar. Simple Impregnation method has been used to prepare form stable composite material which has good thermal and structural stability. The best mixing ratio (PCM: biochar) is found to be 6:4 (wt/wt%) with minimum leakage of PCM from the composite. The sample prepared through this method yield all the desirable properties as compared to other developed samples. The chemical properties of the composite remain the same as the pure PCM, which confirms no chemical interaction between the PCM and biochar. The heat of fusion is calculated to be 179.4 J/g. The thermal conductivity of the PCM is enhanced up to 13.82 times with the addition of water hyacinth biochar as a supporting matrix. The addition of aluminum metal powder further increases the thermal conductivity by 17.27 times higher than that of PCM alone.

1. Introduction

Fast-growing economies have created an increase in energy demand at an unprecedented scale. However, limited fossil fuel reserves are insufficient to satisfy this need. Thus, renewable energy is looked upon viewed with trust by the world scientists and energy providers. Of all the renewable energy sources the solar energy is one of the accessible and reasonable choices. The major drawback of renewable energies, such as solar power, is their intermittency. This is where thermal energy storage is of great importance. The surplus thermal energy generated during the sunshine hours can be stored using an energy storage media. Factors considered in the selection of heat storage materials include cost, storage density, environmental impact and reliability. Recent years have seen an increasingly intense research effort devoted to the study and application of phase change materials (PCMs), which demonstrate ideal capacities to store and discharge abundant thermal energy during the course of phase change. However, low heat conductivity, as well as the problem of liquid leakage during phase transitions, have become the two significant shortcomings. For instance, the solid–liquid transition must be suitably contained to prevent leakage. There are two ways to deal with pure PCMs to improve their stability and performance. The first one is to make form-stable PCMs, which is a network on micro or macroscale where PCMs are trapped. Whereas encapsulation is applied in the second case. The additional use of encapsulation may incur additional cost on the system and add up heat resistance caused by the capsule shell, thus reducing the effectiveness of heat transfer during utility mode. The low thermal conductivity of commonly used PCMs is another technological problem to be addressed. This leads to poor life stability of PCM containers and heat exchanger tubing, and also decrease the number of effective cycles they

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ENERGY SOURCES, PART A: RECOVERY, UTILIZATION, AND ENVIRONMENTAL EFFECTS
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Experimental analysis of photovoltaic-thermal collectors with closely spaced tubes

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ABSTRACT

Solar Photovoltaic (PV) systems have become increasingly popular in the last decade due to continuous increase in conversion efficiency and significant reduction in per unit generation cost. Photovoltaic-thermal (PV/T) collectors have been gaining popularity to utilize Sun's spectrum effectively for production of electricity and utilization of waste heat. In the present study, two independent serpentine PV/T collectors having small gap between tube columns are designed to obtain desired temperature for domestic use with limited collector area and to achieve better cooling uniformity. PV/T-I has a copper absorber plate attached to the rear surface of the PV module and tubes are brazed to the plate, while PV/T-II has only tube for fluid flow which is glued to the PV back. Both the PV/T's have a back cover to protect the tubing from moisture and dust. PV/T's are tested under outdoor conditions during September–December, 2018. The developed PV/T's are analyzed using the energetic and exergetic method. The average energy and exergy efficiency for PV/T-I is found to be 62.28 ± 5.53% and 12.27 ± 5.58%, whereas for PV/T-II average energy and exergy efficiency found to be 51.13 ± 5.53% and 13.4 ± 5.58%, respectively.

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KEYWORDS
PV/T solar collector; serpentine collector; absorber plate; thermal efficiency; exergy efficiency; heating rate; hot spot investigation

Introduction

Economic development and access to clean affordable energy become a priority for most of the developing nations. Energy availability and consumption have become important worldwide, since the magnitude of per capita energy consumption has emerged as one of the key indicators of modernization and progress in a given nation (Kaygusuz 2009). The best quality coals and oil are distributed unevenly thus limiting energy supplies and services. The energy crisis issues in the past and global climate change have created an atmosphere conducive for growth of renewable energy deployment. India has also become active in the issues of energy security due to its economic policy change after the 1991 crisis (Wadhva 2000) and became an endorser for renewable energy. Solar energy is one of the widely exploited renewable energy sources due to its abundance across the globe. Several methods of harnessing solar energy were developed in the last few decades. Among those methods PV conversion route is both technically and economically superior to the other solar energy conversion technologies, it converts the visible spectrum of solar spectrum directly into electricity (Demirbas 2007). The electrical output of the PV system relies on meteorological factors such as the solar irradiance, ambient temperature, relative humidity, and wind speed (Wasfi and Member 2011). The efficiency of the PV system is a strong function of both the solar irradiance and operating temperature (Chokmaviroj, Wattanapong, and Suchart 2006). In general, PV cell is higher than the ambient temperature because of higher value of absorptivity of the cell material. Normal Operating Cell Temperature (NOCT) (Ambient temperature = 20°C and irradiance = 800 W/m^2) which is considered

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Development of a novel thermal model for a PV/T collector and its experimental analysis

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ARTICLE INFO

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PV/T collector
Thermal model
Contact resistance
Ohmic loss
Electrical efficiency
Thermal efficiency

ABSTRACT

In the present study a novel thermal model for a PV/T system is developed which includes the thermal contact resistance between the layers of a PV/T system and individual resistance of the layers. This model provides a clear understanding of how the properties of individual layers of a PV/T module influence its overall performance. The developed model is quite detailed and therefore it will be useful to precisely analyse newly developed tube and sheet PV/T systems. The present model has been compared with an earlier model developed. It is further validated using the present experimental data. It is observed that both the experimental and simulation results of the developed model are in good agreement. The Root Mean Square Errors (RMSE) of 3.75 K, 1.36 K and 2.71 K were reported for the water outlet temperature, glass surface temperature and cell temperature, respectively. The present numerical simulation results illustrate that consideration of thermal contact resistance and Ohmic loss at PV layer reduces the errors significantly. It has been reported from the present experimental study that the electrical, thermal overall energy and exergy efficiencies vary from 12.24–13.02%, 18.16–41.83%, 19.1–28.9% and 8.89–10.03% respectively.

1. Introduction

There is a never ending requirement of energy to keep the civilisation alive. From the beginning of industrial revolution in 18th century, the humankind has been using the non-renewable resources, such as, coal and petroleum. Fossil fuels are formed naturally through millions of years. But these are consumed by an ever increasing amount compared to their rates of replenishment. Therefore, these resources are going to be exhausted soon (Judkins et al., 1993; Rahman, 2017). It has been observed that after repeated energy crises (in 1972 and 2008), the countries across the world have adopted renewable routes of energy generation in order to achieve energy security and economic stability (Al-Maamary et al., 2017; Das et al., 2018). In the recent past, various renewable energy systems have been reported for a sustainable power generation. Among all the renewable energy sources available solar energy is found to be an appropriate alternative to conventional energy sources. Solar energy has become economical and reliable due to availability of solar radiation across the globe and technological developments (Purohit and Purohit, 2018). Many technologies exist for harvesting useful energy from solar energy which are now mature, economical and sustainable. The two main routes of solar extraction is by using PV and thermal collectors. Photovoltaic (PV) technology is a common and effective solar energy capturing technique available till date that can convert 5–25% only of the incident radiation to electrical energy and the rest is unutilized. PV cells have gone through extensive research since 1883 when Charles Fritts developed solar cell with the conversion efficiency less than 1% (Hersch and Zweibel, 1982).

Recently, United States Department of Energy is reported to have produced solar cell with more than 40.7% of electrical conversion efficiency in the laboratory conditions (Worldwatch Institute, 2018). The solar energy available at the ground level comprises of 38.3% of visible light, 8.7% of ultraviolet and 47.4% of infrared (IR) electromagnetic radiation (Scofield, 2009). Currently available PV modules are capable of converting a portion of the visible light only to electricity. For a typical PV module, 5–25% of the incident radiation on the front surface of a PV module is converted to electrical energy and the rest is unutilized and this unutilized IR radiation results in a rise of PV temperature (Atkin and Farid, 2015; Kant et al., 2016a). Thus, the elevated temperature of a PV cell finally results in a decrease of PV electrical conversion efficiency (Skoplaki and Palyvos, 2009). The electrical conversion efficiency decreases linearly with an increasing temperature. The temperature coefficient of a PV cell (with respect to a reference temperature mentioned by manufacturer ≈ 298 K) is expressed as (Dubey et al., 2013; Evans and Florschuetz, 1977),

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Flat plate hybrid photovoltaic- thermal (PV/T) system: A review on design and development

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ARTICLE INFO

Keywords:
Photovoltaic-Thermal (PV/T)
Nanofluid
Heat pipe
Phase change material (PCM)
Enviro-economic analysis
Exergy analysis

ABSTRACT

Carbon dioxide emissions from burning fossil fuels are believed to be the main factor for alarming rise in global temperatures. Conference of Parties 21 held at Paris in the year 2015 strictly warned and asked the nations to reduce their greenhouse gas emission level. This makes the nations to adopt renewable energy technology to substitute burning fossil fuels. Solar energy due to its accessibility and affordability leads the renewable energy application race. Even though Photovoltaic (PV) technology is mature but the effect of temperature on its efficiency is considerable, which opens up new front of research where combination of PV and thermal absorber is focussed to harness thermal energy which otherwise negatively affect the PV electrical efficiency. In the proposed study starting from the effect temperature on PV electrical efficiency, construction of Photovoltaic-Thermal (PV/T) module, historical development of PV/T, about different types of PV/T's developed around the globe along with performance of developed PV/T's, effect of operating parameters and methods of thermodynamic management are reviewed and presented. The study emphasised on the use of nano fluid and phase change material to harness maximum thermal energy from the system, also includes an insight into commercially available PV/T modules across the globe. This paper presents enviro-economic evaluation of PV/T systems developed by various researchers and also enumerated thermodynamic methods for evaluating system efficiency, which includes both energy and exergy analysis. This paper also provides the necessary information about the requirement of future research in PV/T.

1. Introduction

Energy usage, its accessibility and affordability will continue to be at the core ingredients of development, economic growth and poverty alleviation. With globalisation and improvement in the standard of living, the concept of development has transformed from mere development to sustainable development. The countries across the world will be expected to provide not only the basic freedom enshrined in their respective constitutions, but also the most basic rights to clean air and right to clean drinking water. The global energy agenda not only concerned at efficiency improvement but it has revolved around the concerns of climate change and global warming. Most of the energy projects require large capital investment and have long financial payback periods. However, the brighter side is that there has been a dramatic fall in the prices of new and renewable energy sources, especially solar [1].

The global energy consumption in the last century almost increased eleven-fold. The largest increase in rate of consumption has been in the coal, oil and gas divisions. The fossil fuels together constitute almost 87% of total energy demand of the world [2]. Carbon dioxide emission from burning fossil fuels is believed to be the main factor influencing an alarming rise in global temperatures. In 2004, the average atmospheric carbon dioxide concentration reached 377.4 ppm by volume. The safe level of carbon dioxide in the atmosphere is 350 ppm. In the recent time global levels of CO_2 concentration in atmosphere have crossed 400 ppm [3]. Reported concentration of CO_2 in the atmosphere as reported in September 15, 2017 is 403.78 ppm [4]. The level of CO_2 increase can be observed from the Keeling curve as shown in Fig. 1. Already the harmful effects of climate change can be seen as rising seas, wildfires, killer cyclones, and extreme weather. Passing 400 ppm mark of carbon dioxide concentration in our atmosphere is an ominous sign of what is waiting for human civilization.

The oil crisis in the 1970's and the global climate change concerns are really alarming the need of alternative clean energy sources. Again, in 2008 oil crisis of the Arab region opened up the energy market to a new source the 'Shale Oil', but its sustainability is still a debate. This, 2008 oil crisis leads to adoption of renewable energy generation options in the Arab region [6]. Conference of the Parties, twenty-first sessions

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