International Journal on Emerging Technologies 10(2): 01-07(2019)

ISSN No. (Print) : 0975-8364
ISSN No. (Online) : 2249-3255

SWOT Analysis of Solar PV Systems in Airport Environment

S. Sreenath[1], K. Sudhakar[2,3] and A.F. Yusop[2]
[1]Energy Efficiency & Renewable Energy Research Cluster, Universiti Malaysia Pahang, 26600 Pahang, Malaysia
[2]Faculty of Mechanical Engineering, Universiti Malaysia Pahang, 26600 Pahang, Malaysia
[3]Energy Centre, Maulana Azad National Institute of Technology, Bhopal, (Madhya Pradesh), India

(Corresponding author: K. Sudhakar)
(Received 02 April 2019, Revised 01 June 2019 Accepted 08 June 2019)
(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT: The harmful effect of global warming is nightmare in all spheres of earth especially coastal cities and societies. In this context, the role of solar PV installations in the mitigation of carbon footprint is relevant. The airport lands are relatively new application of solar PV and are in evolving stage. This paper discusses about the role of airports in ecological imbalance and suitability of solar PV installations in airport environment. A SWOT analysis on airport solar systems is carried out and it focuses on internal and external factors, current and future potential that affect the success of such projects. This work is expected to give an insight into the development of strategic planning for airport solar PV power plant.

Keywords: Airport, Carbon dioxide, Solar PV, Planning, SWOT

I. INTRODUCTION

Many countries are witnessing harmful effects of climate change and global warming. This can be correlated to the rise in green house gas emissions, mainly Carbon Dioxide (CO_2) caused by human activities such as burning of fossil fuels and deforestation [1]. As of April 2018, the average monthly level of CO_2 in Earth's atmosphere exceeded 410 parts per million (ppm) [2]. The present concentration of CO_2 may be the highest in the last 20 million years [3]. The global mean CO_2 concentration is currently rising at a rate of approximately 2 ppm/year and is accelerating to higher value [4-5] With the present rate of fossil fuel usage, 450ppm limit will be exceeded by 2034 [6]. This may reduce the possibility to keep the rise in global temperature at 2°C. The consequence will be dangerous and irreversible [7]. In this regard, it is important to reduce emission of green house gases such as CO_2 at the earliest from every sector of human activities. In addition, the global demand for energy is exponentially increasing. Most of the nations still majorly depends on limited fossil fuel reserves so as to generate electricity, more pronounced in Asian and African countries. As a result of which, there is a serious issue of rise in cost of electricity and ecological damage.

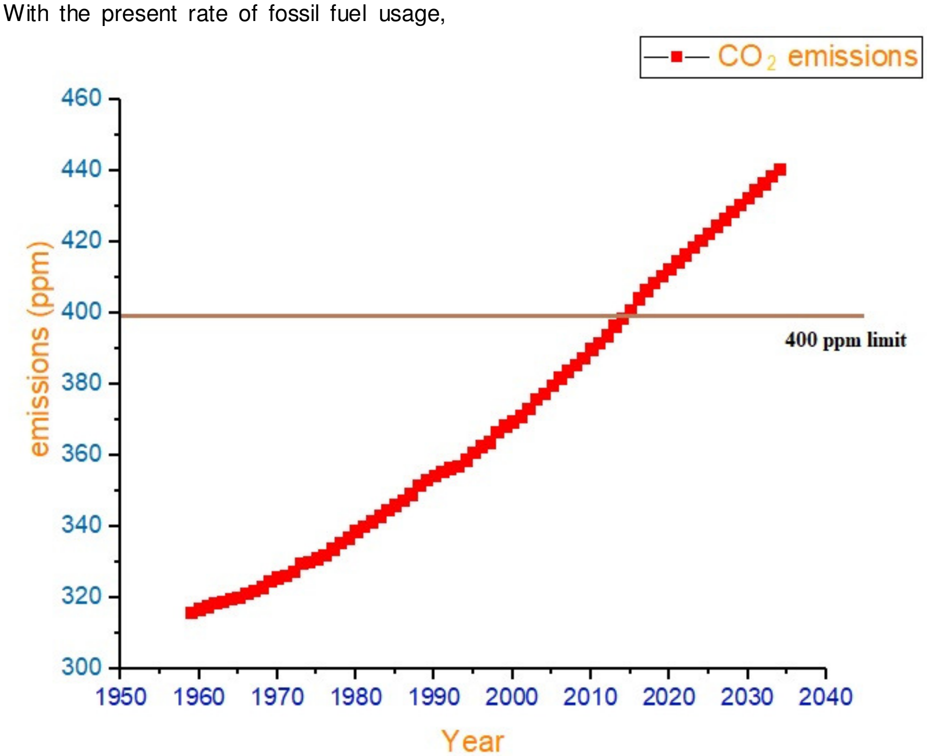

Fig. 1. Rate of rise in carbon dioxide emission (ppm) with respect to year.

The role of transport sector in air pollution is huge, comes after the combustion of coal. The green house emissions due to road, rail, air and water/sea transport is one of the main reason for acid rain, ozone depletion and climate change [8]. The aviation industry has significant role in the rise of green house gas concentration in atmosphere. As per statistics, the exhaust gases from aviation contribute to 3.5% of global emissions and its share is expected to double in the coming fifteen years [9]. The negative ecological impact from airport cannot not be estimated from single dimension. Initial stage of airports construction involves modification of the landscape and ecology of the airport location on large scale which might lead to considerable environmental damage. The negative impact of aviation industry in general and airports in particular, includes landscape modification, noise, air pollution, local climate change, excessive water use, and effects on the social structures of local communities. However, positive benefits include direct and indirect employment, and social (and economic) usefulness to passengers which in sustains the operation of existing airports as well as development of new airports [10]. The negative impacts can be classified as direct and indirect ones. Direct impact involves aircraft noise on nearby community and aviation emission on local air quality and global climate. The working scenario in airports has changed dramatically in the last decade, in terms of energy requirement and passengers handling. The increase in the number of travellers lead to rise in the energy consumption in many airports. The landing and takeoff of aircraft causes emission of carbon particulates into atmosphere. Also aviation field produces a number of other pollutants besides carbon dioxide including nitrogen oxides (NO_X), particulates, Unburned Hydro Carbons (UHC) and contrails [11]. Higher atmospheric concentrations of greenhouse gases notably carbon dioxide (CO_2), methane, NO_x and others cause the atmosphere to absorb more heat from the earth's surface, and lead to higher levels of global warming, or climate change. The indirect impact corresponds to the usage of electrical energy and other energy fuels in airports. The electricity demand in airports is met mainly through electricity generated from conventional energy sources such as coal, natural gas, petroleum etc. Electricity consumption in airports is mainly on air-conditioning, lighting of the internal space of the building, the airfield and the electromechanical installations [12]. Most of the electrical energy is consumed for meeting heating and cooling loads. The operation of Heating, Ventilation, Air Conditioning (HVAC) loads in airports lead to release of harmful green house gases and chlorofluorocarbons into atmosphere. The round clock operation of airports makes an airport, even regional one energy intensive. Energy costs account for about 10% to 15% of an airport's annual operational budget [13]. To add on, fossil fuels based energy cannot power an airport throughout its lifetime. The first oil shock occurred in 1973 which caused shot up of oil prices four fold. Similar situation occurred in 1979 and 1990 which fuelled the need to shift from conventional energy sources to alternate sources such as solar, wind and biomass etc [14]. An alternative energy source will be needed at some point of time for airport operation. So it will be in best interest of airports to choose sustainable way of electricity use. Section II describes about compatibility of solar PV systems in airport ecosystem. The information on solar PV systems already installed in airport such as installed capacity, location, and lesson learnt etc is provided in Section III. The main objective of the present work is the analysis of Strength, Weakness, Opportunities and Threats (SWOT) for airport solar PV systems. Other renewable energy technologies such as wind, biomass implemented in airport environment is comparatively less relevant and hence are out of scope in this study. Section IV details about the SWOT analysis with explanation for each parameter. The conclusion obtained from this study is given in Section V.

II. SUITABILITY OF SOLAR PV SYSTEMS IN AIRPORT

Solar PV system consists of PV modules which convert sun's light energy to electricity (DC). The implementation of solar energy technologies has immense scope in tropical countries as compared to other locations [15]. Since the power output of single PV module is less, multiple modules are connected until the amount of electricity generated is consumable or deliverable. Most appliances utilize alternating current (AC), due to which power flow in AC is preferred which allows many appliances to draw off energy from a single system [16-17]. Therefore, the solar facility includes an inverter, which converts the electricity from DC to AC form which is either consumed on-site or exported to the electric grid. Four different types of solar PV project designs are suitable for airport installations namely ground-mounted, roof-mounted, canopy supported and buildings integrated. Moreover, solar plant has little to no maintenance cost due to absence of moving parts (in most cases). Unlike construction of airport and power plants, environmental effect during installation of solar plant is very low as there is no need for large machines and foundation. Solar plant provide reasonably long product warranty of about 25 years. Certain plants that were installed 25 years back are still providing electrical energy [18]. The huge energy costs for airports can make the payback from solar relatively faster than other PV systems. In a land lease or Power Purchase Agreement (PPA) situation where the array is owned and managed by a third party, these are virtually no up-front cost for the facility. Airports like that in New Mexico make use of grants from funding agencies like FAA. Airport grounds are usually large enough to accommodate free-standing PV arrays. It can also serve as noise-barriers by deflecting noise from aircraft [13]. [13]. Since airports are visited by millions of people each year, solar PV plant creates awareness about the technology and its significance to travellers. Demand side management techniques are necessary to avoid system instabilities from rising electricity demands centres like airports. It involves amendment of load curve such as peak clipping, valley filling and load shifting. In this regard, installation of RE system such as solar PV in airport can be beneficial [19]. At the same time, due to intermittent nature of solar irradiation, optimisation techniques based on probabilistic approach, graphical approach, using simulation programs, probabilistic approach, operating point control (MPPT) or artificial intelligence have to be employed so as to maximise efficiency, maintain constant voltage, stable frequency, reduce harmonics within limits [20]. Among MPPT techniques, artificial intelligence method is gaining popularity in recent days due to its high efficiency, fast convergence speed, ability for both analog and digital control and lack of periodic tuning requirement [22]. Internet of Things (IoT) can be applied and utilized for accurate prediction of environmental parameters such as solar irradiation, wind speed, temperature etc [24]. Airport landscape is well suited for implementation of solar projects because

(i) Effective land utilisation: Accelerated development of energy sources including solar and wind has generated numerous conservation concerns, especially while installing new ones [9]. Surrounding land in airport is often not suited for other uses due to aviation regulations and noise from low flying aircrafts. In this regard, the potential for alternative energy production at airports can be utilised for installing solar power plant [10].

(ii) Area availability: Airports have a lot of ground and rooftop space. Since Airport premises consist of buildings that are typically large, isolated (low-rise structures with little or no shading), there is plenty of rooms to accommodate PV modules on rooftops, façades, and parking lots [23]. Solar system can work more efficiently in airport area since there is no or negligible shading factor

(iii) Environmental benefit: The solar initiative in airport is good for the environment as well as for revenue generation. Airports create an immense amount of air pollution and solar can help to offset some of those emissions. The environmental impact of energy from solar depends on the location and solar insolation. Airport solar being strategically located with no damage to forest cover and wildlife should be more beneficial than large scale solar power plants in other off airport sites [11].

(iv) Economic advantage: Solar module cost has come down from $ 2.60 to $0.80 per watt and the cost of the components of PV systems such as racking, inverters are reducing gradually. In this way, solar systems have become more economically viable around the world [19]. Once find the suitable lease terms, solar plant can become a significant non airline revenue source.

(v) Generation follows demand: A good match can be observed between air conditioning loads and PV panel maximum power output. While the airport buildings calls for high energy in warm and sunny climates due to the extensive use of air-conditioning units in large open areas, the solar energy output also will be more due to better insolation and long daytime [12].

Unlike typical solar PV plants (land based or roof mounted), the implementation of airport based solar projects is complex. Solar systems in airports must be sited properly so that it do not cause safety problem for aviation or disrupt aeronautical and airport activities. The spatial data such as airport building location details, boundaries across the airport, data regarding object free zone, runways, location of future buildings and extension work for existing runways etc are needed for sitting of solar PV in airport.

1. Solar PV modules reflect sunrays falling on it and its extent depend on sun's position and PV module type. This causes glint (a momentary flash of bright light) and glare (continuous source of bright light). Such glare occurrence may affect the visibility of Air Traffic Control officials, pilot during landing and takeoff which is a compromise on the safety of air transportation system. So the location and orientation of solar modules have to be chosen in such a way to eliminate the potential for harmful glare to pilots or air traffic control facilities. Federal Aviation Administration (FAA) in partnership with US Department of Energy (DoE) has established standard for the estimation of glare/glint, and found out a threshold values at which glare and glint would impact aviation safety. Computer aided glare analysis can be employed to examine the glare hazard over the entire year in one minute intervals from sun rise to sun set.

2. There is possibility of radar signals being interrupted if solar PV modules are sited close to radar systems. In order to limit the potential for interference with communication, navigation and surveillance (CNS) facilities, solar energy systems must be located out of critical areas surrounding CNS facilities. Though the risk may be low, a setback of 500 foot radial distance must be maintained between the CNS systems and PV modules.

3. The sites chosen for solar PV system must be consistent with the future development of airport. In this regard, airport layout plan and master plan have to be reviewed along with the consultation of airport authority. Before the construction begins, airport administration has to get approval from aviation authority if the proposed solar installation changes the footprint of existing buildings or structure on its Airport Layout Plan (ALP).

4. No physical structure is allowed to intervene in space that may lead to any safety issues at airports.. Such location is decided by the height of the structure and its closeness to the airport runway. Since the height of solar PV system is low profile, the point of concern is the area around the runway only. Using the area map of airport, the land area that is not in conflict with the restricted area have to be identified.

In addition, sites that are close to electrical infrastructure and cause least environmental impact are preferred over other locations. This helps in reduction of project cost and speedy environmental approval. Usually, the project developer is the airport administrative or Third Party Company. Once the PV sites and its design is finalised, then the project developer has to obtain clearances from different offices mainly from airport authorities, aviation regulatory, state electricity utility, environmental board. Proper communication between project developer, airport officials and regulatory boards is important for timely completion of a proposed airport solar project. Few installations are less successful due to inadequate planning and analysis. Detailed planning and sitting studies including consideration for glint and glare potential, wildlife impacts, system performance and safety is needed for successful implementation.

III. EXAMPLES OF AIRPORT SOLAR PV (ASPV) SYSTEMS

Solar PV systems have been implemented successfully in airports. Cochin International airport has successfully implemented solar systems in its premises thereby becoming the world's first fully solar powered airport. The Cochin airport authority installed 12 MW ground mounted system, lying close to cargo complex. The airport plans to extend its solar capacity up to 40MW (including 6-MW canal-top solar project, 2.7 MW on car park) to meet its future requirement. In addition, solar PV projects can benefit the society in terms of social improvement and income generation [25]. Adelaide Airport, Australia has installed 1.17MW capacity solar system consisting of high quality tier1 260 Watt solar panels with DC power optimisation, thereby providing safe and reliable renewable energy of 1,768 MWh annually which accounts for 8.5% of total electricity use [26]. Kathara airport, Western Australia installed 1MW solar project. But the intermittent cloud cover resulted in huge, sudden variations in solar electricity output. To address this, the installation facility incorporates a generation management system (GMS) with cutting-edge cloud predictive technology (CPT). The 2.5MW solar system in Tucson airport solar project lead to environmental benefits such as reduction of 25,000 gallons of gas burned and 245 tons of carbon dioxide per month. The 2.1 MW solar farm in Chattanooga airport, United States is located in an area unusable for aviation purposes. This project was funded through a Federal Aviation Administration (FAA) Voluntary Airport Low Emission (VALE) Grant. The 2.5 MW solar plant spreading on 10 acres in London Southern airport is one of the largest on site solar installation at an European Airport. This plant can meet 20% of the annual energy consumption of airport and has significant positive impact on its carbon footprint which helped it in voted as UK's best airport and one of the most sustainable airports in the world. Certain guidelines and precautions that must be considered during solar PV installation in airport was mentioned by Sukumaran and Sudhakar for in the proposed 2MWp in Raja Bhoja airport [26]. The 2MW solar system among the 10MW airport RE system in Denver International airport is single axis tracked and suffered hydraulic and other operational problems which in turn affected energy production. The abundant sunshine in Southern Arizona along with the FAA grant money helped in the commissioning of 1.0 MW canopy mounted PV system mounted in Tucson airport. Chicago Rockford International Airport installed 3MW ground mounted solar system and it was challenging as it located near to the runway protection zone. The central issue was to ensure that the proposed project will not affect sensitive receptors and navigational aids. Barnstable Municipal Airport (HYA) opted for 5.7MW ground mounted PV system so as to add its revenue base from non-traditional sources such as parking, airline fees, rent etc [27]. It was reported that adjustments to solar arrays were needed to resolve glint and glare issues which helped to obtain no hazard determination from FAA. The solar PV system in Redding Municipal Airport occupies about three acres of land located close to the terminal and existing electrical infrastructure. A portion of the Runway Protection Zone (RPZ) of Lakeland Linder Field airport (LAL) is used for solar PV installation. Indianapolis International Airport (IND) solar PV project consist of two project implementation phases, first phase using a fixed panel system (commissioned in October 2013) and the second phase with single axis tracking system (commissioned in December 2014).The role of Indianapolis Airport Authority is to acts as a landlord for the facility and receives an annual lease payment. Being small and busy, the land availability in San Diego (SAN) international airport for lay down and storage is minimal. This created a problem for mobilizing and preparing the construction operations related to solar PV plant.

IV. SWOT ANALYSIS OF ASPV SYSTEMS

SWOT analysis is one of the widely used tool for strategic planning all over the world. SWOT analysis is a framework used to evaluate the competitive position of a project. The term SWOT is the acronym made up of four words namely Strengths, Weaknesses, Opportunities and Threats [28]. It considers internal and external factors, current and future potential with respect to a project. Usually a SWOT analysis is presented as a square with each of the four areas making up one quadrant. This visual arrangement provides a quick overview of projects feasibility. Although all the points under a particular heading may not be of equal importance, these points represent key insights into the balance of opportunities and threats, advantages and disadvantages, and so forth. SWOT analysis gives an idea about the healthiness of a project especially if it is relatively new. It helps in formation of a strategy so as to make preparation for the possible threats [29]. The Strengths, Opportunities, Weakness and Threats (SWOT) associated with installation of solar PV power plant in airport environment is discussed in this section.

A. Strengths

Solar PV systems can readily customised to any area identified in airport property. The flat design of solar panels makes it convenient to attach to a variety of location such as poles, parking lots and other human made structures. Since sunlight reaches every part of earth, it can be deployed at some locations in all airports around the globe. The low height profile of solar PV reduces the physical obstruction and a safety risk to safe navigational operation. In certain cases, it can also be placed in many locations in the airfield, including in close proximity to runways without resulting in a physical impingement on airspace. The importance of solar PV based power generation is expected to increase in future with rising demand for renewable energy certificates and carbon credits. A good match can be observed between air conditioning loads and PV panel maximum power output. Solar plan provide reasonably long product warranty of minimum 25 years. Unlike construction of airport and power plants, environmental effect during installation of solar plant is very low as there is no need for large machines and foundation. Airport property is an attractive spot for local power generation due to their high density of power consumption and their distance from power generating centres.

B. Weakness

Since solar PV can provide electricity only during sunshine hours, an alternate source must be activated to fill the deficit. This mandates for storage of solar electricity in batteries (makes the system more expensive) or to draw electricity from grid at night time (micro grid). In reality, when factoring night-time, weather interruptions, and geographic location, solar panels typically only produce on average approximately 15 per cent of its installed capacity. This is less than other Renewable Energy Technologies (RETs) such as hydro, wind etc. Still the initial investment for MW scale solar power plant is huge which in turn affects the return on investment. The amount of electricity generated and efficiency of the system varies among locations, with the sunniest areas producing the most electricity per panel. The power conversion efficiency of solar PV module is between 18 to 23% for first generation solar cells. Due to this, the land footprint of solar power plants is huge. As rule of thumb, five acres are earmarked for 1MW for crystalline silicon based solar PV plant.

C. Opportunities

Solar PV system makes use of underutilized property, either undeveloped land or on buildings or over surface parking. Solar provides a stable cost of power (with no operational fuel cost and least maintenance cost) and against volatile fossil fuel prices and savings in airport energy bill. Solar PV onsite plant can be a significant non airline revenue source. There is virtually no up-front cost for the facility in certain instances. All sorts of new solar PV innovations are in development and expected to be available in the near future. Thin-film technology is a product that would allow surfaces to be more easily covered in solar PV. In addition, solar ready building materials including roof shingles will allow builders to provide solar energy as part of new construction. RE projects improve the power reliability in airport especially at the time of grid failure and power outages. This helps in energy independence and effective load management. It helps to reduce carbon footprint, thus supports the climate change initiative of the regional authority. Since airports are visited by millions of people each year, solar PV plant creates awareness about the technology and its significance to travellers (environmental stewardship). In addition, airport administration can claim for grants from various governmental and nongovernmental funding agencies for the implementation of such environmentally relevant projects.

D. Threats

The threats can be interpreted from two different aspects, namely airport safety and environmental impacts. Because solar panels have a smooth and shiny surface, it may cause glare particularly when the sun is low in the sky and affect the visibility of pilot and air traffic control officials. If not proper sited, solar PV system posses interference to navigational aids (NAVIDS) and cause physical penetration into safe navigational airspace. In certain cases, solar PV installation cause potential environmental issues such as habitat and wetland disturbance, water quality degradation, hazardous materials etc. The selection of suitable project implementation model is complicated as it is difficult to attract investors and project developers in the absence of concessions or grant. The site selection must be consistent with Airport Layout Plan (ALP). Traces of elements such as tin and lead, copper and zinc are present in PV modules which might discharge to environment if proper handling and disposing steps were not adopted [30].

Table 1: SWOT analysis for airport based solar systems.

Strength	Opportunities
➢ Solar PV systems can be designed or tailored according to the plot identified in airport property. ➢ Solar PV modules can be easily fixed in various locations such as poles, parking lots and other human made structures due its to flat and modular structure. ➢ Since sunrays falls on almost all part of earth, solar PV systems can be deployed at some locations in all airports around the globe. ➢ The vertical height of solar PV structure is low which in turns allows its installation near to runways without resulting penetration into air surfaces. ➢ Airport property is an attractive spot for local power generation due to their high density of power consumption and their distance from power generating centres. ➢ Often the air conditioning loads in airports synchronise with the variation of power output from solar PV system. ➢ Solar PV modules have already proven lifetime of more than 20 years. ➢ When compared to the construction of an airport or power plant, solar PV systems can be installed easily and fastly without the use of large machines and deep foundation.	➢ Use of solar electricity helps to reduce airport's energy cost and safeguard against fluctuating fossil fuel price. ➢ With suitable implementation model, solar PV systems have the potential to become non airline revenue source. ➢ Upcoming developments in the area of solar PV technology and its new applications can benefit airport sector also. ➢ Solar PV projects can help in load management and improve the power reliability in airport especially at the time of grid failure and power outages. ➢ Solar PV systems can be installed in those parts of airport property which for aviation purposes i.e. better land utilisation. ➢ Solar PV systems help in carbon mitigation and thus support the climate change retardation goals of aviation sector. ➢ The environmental stewardship and social responsibility of airports can be perceived by millions of passengers. ➢ Grants and loans schemes by various governmental and nongovernmental funding agencies can be utilised for such projects.
Weakness	**Threats**
➢ A solar PV system can provide electricity only during sunshine hours which in turn necessitates for battery storage or grid interconnection. ➢ The initial investment is huge i.e. about five Crore for 1MW solar PV plant ➢ The capacity utilisation factor of typical solar PV plant is (15 to 18%) which is less than other RETS such as small hydro, wind, biomass etc. ➢ Due to low conversion efficiency of solar PV module, the vast area is needed for installation of solar power plants.	➢ The glancing reflection from solar PV module can affect the visibility of pilots and officials in Air Traffic Control Tower. ➢ Improper site selection may cause interference to communication and surveillance systems in airports and penetration into navigational airspace set by airport authorities. ➢ There is possibility for negative environmental issues such as disturbance on species and wetland, water quality degradation, use of hazardous materials etc ➢ Due to complex design and implementation process, it will be difficult to attract investors and project developers. ➢ Site selection may hinder the airport's future developments and modifications

V. CONCLUSIONS

The concentration of carbon dioxide particulates has crossed more than 400ppm in atmosphere. The operation of airport has considerable adverse impact on environment. Airports are energy intensive and operate for 24 hours.

The significance of solar PV systems is increasing day by day as it is viewed as greenest energy source. Airport landscape is well suited for the installation of solar PV plants. In this regard, solar PV systems of varying capacity have been installed in airports worldwide.

-Since solar PV systems are not common in airport premises, a SWOT analysis on airport solar systems is relevant. It is will provide an overview into future prospects of such solar PV applications.

-From the present study, it was understood that a lot of strengths and opportunities exist for airport solar PV systems. The effective land utilisation, non airline revenue, reduced carbon footprint are the main positive factors.

-Few threats such as improper sitting, glare occurrence, radar interference etc have to be addressed during the design phase to safeguard the navigational airspace. An in-depth analysis in the planning stages for the solar systems is needed for synergistic with airport operation.

-Since the prime concern of airport is safe air transport, local governments and airport authorities are cautious about implementation of non aeronautical activities such as solar PV systems within airport boundary. In this regard, the project developer for airport solar system has to foresee extra time and manpower needed for obtaining the permission from different regulatory bodies.

ACKNOWLEDGEMENT

This study was supported by University Malaysia Pahang (UMP) through Doctoral Research Scholarship (DRS) and Internal grant RDU 1803100.

REFERENCES

[1]. Etheddge, D.M., Steele, L.P., Langenfields, R.L. and Francey, R.J. (1996). Natural and anthropogenic changes in atmospheric CO_2. *J. Geophys. Res.,* **101**(95): 4115–4128.

[2]. B.I.U. Kevin Loria, (2018). The amount of carbon dioxide in the atmosphere just hit its highest level in 800,000 years, and scientists predict deadly consequences. [Online]. Available: https://www.businessinsider.my/carbon-dioxide-record-human-health-effects-2018-5/?r=US&IR=T.

[3]. Change, C. and Basis, T.S. (1974). News from MRPA Sponsoring Agencies. *Midwest Rev. Public Adm.,* **8**(1): 74–83.

[4]. Trends in Atmospheric Carbon Dioxide[Online]. Available: https://www.esrl.noaa.gov/gmd/ccgg/trends/. [Accessed: 06-Feb-2019].

[5]. Rasmussen, C.E. (2018). Atmospheric Carbon Dioxide Growth Rate.

[6]. J. Hansen *et al.,* (2013). Busting the carbon Budget.

[7]. Hansen, J., Kharecha, P., Sato, M., Masson-Delmotte, V., Ackerman, F., Beerling, D.J., Zachos, J. C. (2013). Assessing Dangerous Climate Change : Required Reduction of Carbon Emissions to Protect Young People, Future Generations and Nature. *PLoS ONE,* **8**(12): 816-48.

[8]. Colvile, R.N., Hutchinson, E.J., Mindell, J.S., and Warren, R. (2000). Millennium Review for submission to Atmospheric Environment. Africa (Lond)., pp. 1–28.

[9]. Editorial (2004). Clean, green conferencing. Nature, **432**(7015): 257.

[10]. Health, W., What are an Airport's Impacts?. World Health, pp. 1–30.

[11]. Brasseur, G.P., M. Gupta, B.E. Anderson, S. Balasubramanian, S. Barrett, D. Duda, G. Fleming, P.M. Forster, J. Fuglestvedt, A. Gettelman, R.N. Halthore, S.D. Jacob, M.Z. Jacobson, A. Khodayari, K. Liou, M.T. Lund, R.C. Miake-Lye, P. Minnis, S. Olsen, J.E. Penner, R. Prinn, U. Schumann, H.B. Selkirk, A. Sokolov, N. Unger, P. Wolfe, H. Wong, D.W. Wuebbles, B. Yi, P. Yang, and C. Zhou (20160.Impact of Aviation on Climate: FAA's Aviation Climate Change Research Initiative (ACCRI) Phase II. *Bull. Amer. Meteor. Soc*., **97**(4): 561–583.

[12]. Koroneos, C., Xydis, G., and Polyzakis, A. (2010). The optimal use of renewable energy sources-The case of the new international 'Makedonia' airport of Thessaloniki, Greece. Renew. Sustain. *Energy Rev.,***14**(6): 1622–1628.

[13]. Mills, R. (2011). Airport Solar and Geothermal Power. Thesis.

[14]. Shukla, A.K., Sudhakar, K., and Baredar, P. (2016). Design, simulation and economic analysis of standalone roof top solar PV system in India. *Sol. Energy,* **136**: 437–449.

[15]. A.K. Shukla, K. Sudhakar and P. Baredar, (2016). "Design, simulation and economic analysis of standalone roof top solar PV system in India,". *Sol. Energy,* Vol. **136**, pp. 437–449.

[16]. Kumar B.S., and Sudhakar, K. (2015). Performance evaluation of 10 MW grid connected solar photovoltaic power plant in India. *Energy Reports*, **1**: 184–192.

[17]. Duraisamy, S., Dhanushkodi, S., and Sudhakar, K. (2019). Thermal Performance of Natural Convection Solar Dryer for Drying Chilli. *International Journal of Emerging Technologies*, **10**(1): 133–138.

[18]. Shukla, A K., Sudhakar, K., and Baredar, P. (2017). Recent advancement in BIPV product technologies : A review*. Energy Build*, **140**: 188–195.

[19]. Akash Kumar Shukla, Sudhakar K, Prashant Baredar, (2016). Simulation and performance analysis of 110 kWp grid-connected photovoltaic system for residential building in India: A comparative analysis of various PV technology, *Energy reports,* **2**: 82-88

[20]. Muley, K.C. and Bhongade, S. (2019). Load Management Techniques and Pricing Model for Demand Side Management – A Review. *International Journal on Emerging Technologies,* **10**(1): 42–46.

[21]. Kumar, A., Sudhakar, K., Baredar, P. and Mamat, R. (2017). Solar P.V. and BIPV system : Barrier, challenges and policy recommendation in India. Renew. Sustain. *Energy Rev.,* **82**(xx): 3314–3322.

[22]. Sharma, P.P.K. (2016). A Review Modeling and Control Strategies for Renewable Based Energy Sources. *International Journal on Emerging Technologies,* **7**(1): 141–147.

[23]. Soni, S. (2018). Review of Maximum Power Point Tracking : History, Developments and Challenges. *International Journal of Electrical, Electronics and Computer Engineering*, **7**(2): 07-10.

[24]. Alzubi, J.A., Manikandan, R., Gayathri, N., and Patan, R. (2019). A Survey of Specific IoT Applications.

International Journal on Emerging Technologies, **10**(1): 47–53.
[25]. Bajpal, S. and Sethi, V.K. (2017). Review: Design, Simulation and Economic Analysis for Decentralized and Distributed Power Generation in India. *International Journal on Emerging Technologies,* **8**(1): 70–78.
[26]. Sukumaran, S. and Sudhakar, K. (2017). Fully solar powered Raja Bhoj International Airport: A feasibility study. *Resour. Technol.* pp. 1–8.
[27]. National Academies of Sciences, Engineering, and Medicine (2010). Understanding Airspace, Objects, and Their Effects on Airports. Washington, DC: The National Academies Press. https://doi.org/10.17226/14454.
[28]. Sudhakar, K. (2019). SWOT analysis of floating solar plants. *MOJ Solar Photoen Sys.,* **3**(1): 20–22.
[29]. Kumar, N.M., Sudhakar, K., Samykano, M. and Jayaseelan (2018). BIPV market growth: SWOT Analysis and favorable factors. *4th International Conference on Electrical Energy Systems (ICEES)*.
[30]. Min, H.S., Bouhal, T., Naa, N.S., and Munaaim, M.A.C. (2019). Solar Energy development : Case study in Malaysia and Morocco. *International Journal of Emerging Technologies*, **10**(1): 106–113.

How to cite this article: Sreenath S., Sudhakar K. and Yusop A.F. (2019). SWOT Analysis of Solar PV Systems in Airport Environment. *International Journal on Emerging Technologies*, **10**(2): 01-07.