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ECO-TOURISM SUSTAINABILITY THROUGH PV TECHNOLOGY: A COMPREHENSIVE REVIEW

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Abstract

Through the Economic Transformation program the Malaysian Government aims to consider tourism as one of the major contributors to the country's economy and as an industry that imbibe on the principles of environmental responsibility and sustainable development. The growing challenges in the prevention of expansion in agriculture, forestry and aquaculture, and over-exploitation of the natural resources, have made ecotourism extremely popular as a solution for developing tourism sites. Ecotourism attracts many people who wish not only to explore natural wonders but also to protect them for future generations. Most of the ecotourism sites are presumably situated far from the conventional energy resources and thus transporting electricity to those areas are discussed as inefficient and unsustainable. However, solar Photo-voltaic (PV) system is clean and alternative energy to suffice the energy demands of eco-tourist sites. This paper puts statements of the energy demand in global and its impact on the traditional fossil fuels and proposes PV as an alternative renewable technology pertaining to the eco-tourism application. The paper especially focuses on solar PV systems which not only could supply the energy demand of tourist sites but can also maintain the image of the ecotourism. A case of a model lodge is used for the study, through the energy demand analysis. A comprehensive review on the PV architecture is presented that derive interest in the implementation of such structure for the case presented.

Keywords: Eco-tourism, Solar PV systems, Sustainability, Peak demand.

1. Introduction

In 2012 the world energy consumption grew by 1.4% well below the average annual growth rate of 2.3% over the past decade. The Asian energy market requirement is expected to have an energy demand by 3.6% in the coming years. China experienced a strong slowdown in its energy consumption growth by 50% majorly due to the slow progression of its coal consumption by 70%. India recorded the highest energy consumption increase in 2012 with an increase of 10.5% compared to 2011 due to rise in the demand requirement. The major impact on energy consumption is due to the variations in the weather conditions. As a case in the North America the energy demand reduction in America in 2012 due to mild winter, while under a normal climate the consumption is 1% higher. However, in the European Union increased energy consumption, which is usually 1% lower during normal weather conditions [1-9]. The key challenge ahead is the control on the imbalance of the weather variations across the globe making it very difficult to strategize the balance between energy production and utilization.

Figure 1 shows the global energy production for the past decade on the increase of the production due to various factors including relocations, population increase, improved sophisticated lives, climatic variations, etc.

Figure 2 shows the trend line between the production and utilization and it shows a periodic increase between the demand and the supply. The other side impact of this trend is the environmental pollutions due to the production of energy through conventional resources and also the utility generated carbon dioxide which impact the weather at large.

Figure 3 shows the renewable share of the energy balance chart. The trend on the increase of the share is a good sign; however the renewable which is generally depends on the natural resource availability and its inherent capability of inability to produce the energy throughout the day. The renewable resources need to be addressed heavily by optimizing the way it is handled to maximize efficiency.

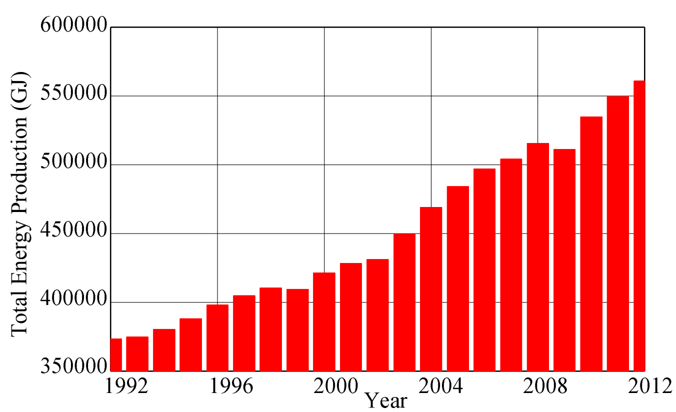

Fig. 1. Global Energy Production [1].

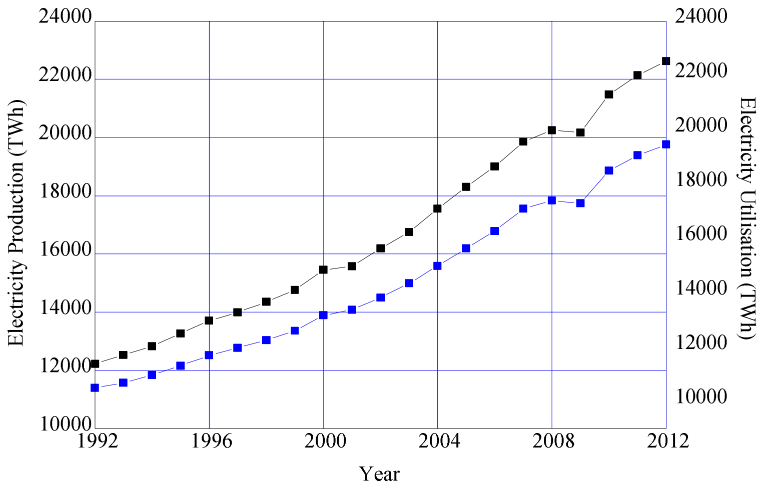

Fig. 2. Global Electricity Productions to Utilization [2].

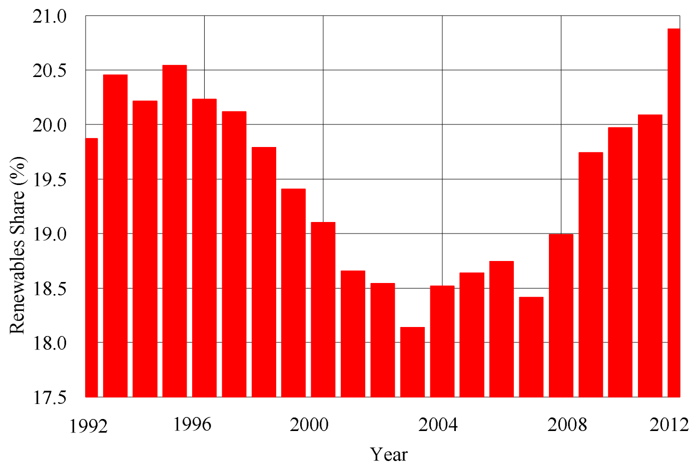

Fig. 3. Renewable Energy Share [1, 2].

2. Eco-tourism

2.1. What is eco-tourism?

Ecotourism is the responsible travel to natural areas or undisturbed areas. Such tourism aims at conserving and preserving the environment as well as improving the quality of life of the local people. It involves knowledge of flora, fauna, environment, culture, heritage, geology, etc. The goal of ecotourism is to provide sustainable development [10-12].

2.2. Principles of eco-tourism?

Though there are no globally standardized ecotourism guidelines for every tourist spot, most researchers oblige to differentiate ecotourism developments from conventional tourism practices on a common set of characteristics. Intelligent building design and sensible practices can help in sustainable development of undisturbed area. In the past years several papers have discussed ecotourism development and highlighted ways of preserving the environment. Some of the principles include [10]:

- Type of use that will minimize negative impact to the environment and local people. Minimize negative impact on wildlife, soil, water, air quality, local people and their culture.
- Understanding of the areas culture and nature and the issues inflicting the area. More interaction between the local people and the visitors can pace the understanding process.
- Conservation and management of legally protected areas by the visitors, e.g., helping management, giving entry fee, donations, volunteer work, etc.
- Participation of local people in decision making regarding the amount of tourism that should occur.
- Economic benefits to individuals rather than restricting traditional activities (fishing, farming, etc.). Involvement of local people in tourism industry, i.e., local people working in lodges, local products purchased by visitors, etc.
- Provide opportunities so that local people and tourism employees can learn more about the wonders of the area, e.g., important events in area, transportation arrangements, etc.

2.3. Design of lodges

The buildings should have an energy efficient design. Listed below are some ways of improving the energy-efficiency of buildings:

- The trees cleared in the process of building road network and lodges should be used for the construction purpose. Timber can be used in the building design [11].
- The building design of the ecotourism lodges should comply with the traditional building design and the use of local material should be appreciated [10].
- The ecotourism lodges should have a passive solar design. This will not only reduce the need for illumination inside the building but will also reduce the need for heating [12].
- Hybrid photovoltaic thermal systems should be installed on the roof of the lodge. They can be used to cater the need of electrification in the lodges as well as provide hot water. The PV/T can be used for heating during winters and ventilation during summers.
- The use of glass-to-glass PV/T can greatly increase the overall energy efficiency of the system. Thus, they can prove to be a better option [13].

- Battery operated boats should be used with the batteries charged by PV. Such boats are silent and do not cause pollution thus, helping in minimizing the adverse effects on wildlife [12].
- Compact Fluorescent lights (CFL) should be used instead of incandescent light. A CFL uses less energy to produce the same wattage as an incandescent light and has a longer life [14-17].
- The ecotourism lodges should have structured plumbing layout. The pipes should be short, with a small diameter and less flow rate. All the pipes should be insulated to prevent heat loss. The insulation should keep the water in pipes heat for 30-40 min. after last hot water event [18].
- A drain water heat recovery system should be installed. It uses the heat from the hot water in the drain to raise the temperature of the cold water [18].
- Demand Controlled Pumps should be used. Unlike other continuous pipes that keep on circulating water at all times even when there is no demand; the demand controlled pumps are actuated only when there is user-demand and the water is not sufficiently heated. This system will help conserve water and energy [19, 20].
- The showers should have a low flow rate in order to conserve water.

2.4. Additional measures

Some of the typical additional measures that could be in place to reduce the power consumption include:

- The lodges should have key cards so that all the lights are turned off as soon as the person leaves the room.
- The tourists should be instructed to use heating, Air conditioning and lights responsibly.
- The washing machines should use cold water instead of hot water. This can save a considerable amount of energy.
- The local people should be employed in the lodges for customer service and maintenance and as tourist guides.
- All the lodge employees should have basic knowledge of the area, its flora, fauna, culture and geology and should be able to answer any questions from the visitors regarding the area [21].
- The carbon offsetting fee should be included in the rent [21].
- Shuttles can be used to take the tourists from place to place. This will reduce the use of independent transport and the carbon emitted from it [21].
- Local and organic products should be promoted [21].
- There should be proper waste management and recycling [21, 22].
- There should be proper visitor centers to provide information regarding the day and night activities in the area. They should provide brochures, leaflets, display posters regarding tourist activities. Quality experience for tourists is very important for sustainable development [23].
- Certifications and trainings will increase the competitiveness in the ecotourism industry and will play a vital role in marketing. Environmental

benchmarking and accreditation will set a quality check and will help improve the industry [23, 24].

- Consultancy on ecotourism can help promote best practices and expertise [23].
- Environmentally sensitive tools should be used. Ecolizer is such a tool that consists of a bunch of cards displaying important environmental related information of different material. Thus, the designer can choose appropriate environmentally friendly material for his particular design [25].

These ecotourism practices and additional measures have profound advantages not only to the sustainability of tourism development but also on the quality of living standards of the local people. Ecotourism also provides the opportunities for the tourism developers and business stakeholders to connect with nature enthusiastic travellers to create lodging projects in remote and off-grid tourism areas.

3. Energy Demands at the Eco-tourist Site [26]

Malaysia being a tropical country average sun insolation ranges about 4.8 $kWh/m^2/day$ – 5.8 $kWh/m^2/day$. In order to maximize this energy output it is required to design a system that optimize the efficiency of the cell. Malaysia being the major attraction for the tourist destination in this part of the world enjoys a bigger share of tourist around the whole year. Figure 4 shows the unit consumption of energy and a sizeable increase during the past few years. Hotel and tourism industry demands stable and reliable energy supply as it is vital to provide electricity for the equipment and appliances to satisfy the customers' needs and comfort.

There are basically two types of energy demand in any hotel within the tourism industry, namely, electricity and thermal energy. The conventional power utilities and services which deliver electricity through grids and networks are primary sources to most of the accommodation areas locate near the grid network. Off-grid areas generally do for the renewable energy resources which include wind, solar, hydro and biofuel. Thermal energy which is usually necessary for heating applications is obtained from fossil fuels or renewable energy resources. The energy demand varies based on the nature of the tourist sites, local climate, the efficiency of the electrical equipment in the hotel, types of the hotels and quality of the maintenance operations. The optimal choice in the use of renewable by extracting the heat or isolating the heat from the conversion process would improve the efficiency of the plant.

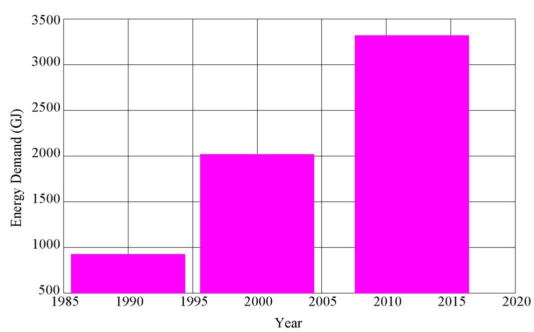

Fig. 4. Energy Demand [1].

For the experimental study the place chosen is Taylor's University in Subang Jaya, Malaysia. A preliminary investigation on the demand analysis is as shown in Figs. 5 and 6. Table 1 shows the percentage share of the pay bill to the Tenaga Nasional. As can be seen the average Peak Demand (PD) is about 20.87% and the kWh utility is about 78.77% for the three year period. If the average peak demand is catered through an energy management system the power system network ideally becomes sustainable.

Table 1. Percentage of Pay Bill Ratio at Taylor's University.

Year	kWh	P_D	Renewable	Penalties
2010	79.38	20.64	0	0.01
2011	78.58	21.35	0.07	0
2012	78.37	20.63	0.09	0

Figure 5 shows the unit consumption and during the second quarter the unit consumption is predominantly high and at the same time the peak demand (as in Fig. 6) is critically very high. The peak demand is addressed through the design of a renewable structure and reconfigures the existing power system architecture in our further investigations.

Although renewable energy sources are preferred energy options for ecotourism site development, it is necessary to rely on back-up non-renewable energy sources (diesel generators) since many eco-tourist lodges are unable to meet the demands of electricity and thermal energy. So, hybrid systems of renewable and non-renewable are important to analyse and research. However, in this context, the main study is to call for decentralized renewable energy sources which preserve the natural resources, protect the environment and develop the sustainable energy supply modes based on the maximum available solar potential exploration at minimum generation costs which fulfil the demands of the tourist sites.

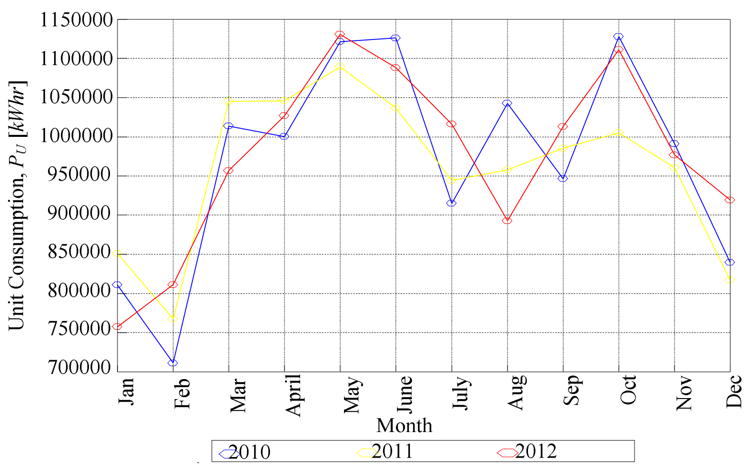

Fig. 5. Unit Consumption of Energy [26].

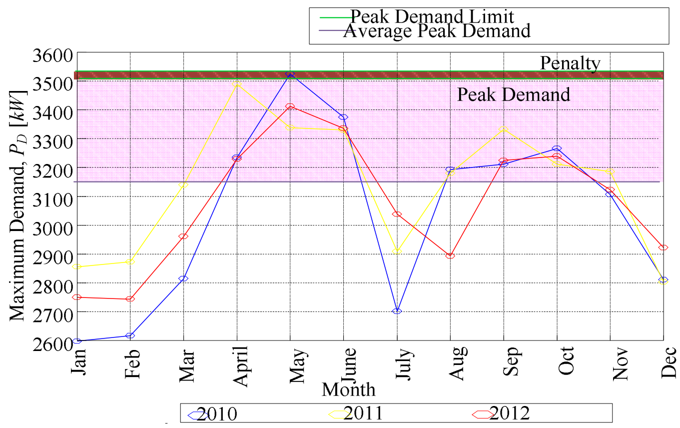

Fig. 6. Power Demand Analysis [26].

4. Solar Technology

4.1. Positive and negative impact of using solar energy technology

The use of solar energy technology has the following advantages [27]:

- Reduction of the emission of the greenhouse gasses (mainly CO_2, NO_x) and of toxic gas emissions (SO_2, particulates)
- Reclamation of degraded land
- Reduced requirement for transmission lines within the electrical grid
- Improvement of the water resources quality.

The socioeconomic benefits of solar technologies include [28]:

- Increased regional/national energy independence
- Creation of employment opportunities
- Restructuring of energy markets due to penetration of a new technology and the growth of new production activities
- Diversification, security, and stability of energy supply
- Acceleration of electrification of rural communities in isolated areas
- Saving foreign currency.

The negative environmental aspects of solar energy systems include [29]:

- Pollution stemming from production, installation, maintenance, and demolition of the systems
- Noise during construction
- Land displacement
- Visual intrusion.

A 1-kW PV system producing 150 kWh each month prevents 75 kg of fossil fuel from being mined. It avoids 150 kg of CO_2 from entering the atmosphere and keeps 473 l of water from being consumed [30].

4.2. Photovoltaic cells

The photovoltaic cell is a semi-conductor that converts sunlight into electricity. When light falls on a PV cell the cell creates holes and electrons. The holes move to the *p* side of the PN junction and the electrons to the *n* side. When an electrical device is connected it completes the circuit. The electrons flow in order to recombine with the holes. Thus, current flows.

The PV cells are combined to form PV panel. The PV panels are rated in Watts and it indicates the power produced in one peak sun hour. Over the year 2010-11 Solar PV was the fastest growing technology worldwide. At the end of 2011, solar PV gained a cumulative installed capacity of 65 GW [31].

Germany has by far the largest solar PV installed capacity. According to the PV magazine Germany hits 32.6 GW cumulative PV capacities in 2013. It plans on installing 8 GW of PV in 2013 [32]. California has the largest solar market in the USA [31]. In 2012, the solar industry installed 3313 MW of solar capacity throughout the country. Additionally, 11 states of the US installed 50 MW or more.

The challenges in the advancement of PV technology parallel induce interests in dynamic energy conversions such as the Wind turbines that convert the kinetic energy in the wind into electrical energy. Wind is present everywhere and can be used to meet the energy demand of the area. However, the use of wind turbines is not the best source of energy in ecotourism resorts due to the electro-magnetic interferences [33] and also inducing negative effects on habitat [34-35].

4.3. Solar thermal systems

Solar Thermal systems convert the solar radiation into heat. These systems offer a number of advantages. Some of them are listed below:

- **Solar hot water**: The collector absorbs solar radiation and heats fluid in a pipe lying underneath it. This hot water is in turn used to fulfil the domestic needs throughout the year, thus, reducing the demand for electricity and peak load [36].
- **Solar space heating and ventilation**: Solar thermal system can be used to heat the air inside the house thus making it comfortable during winters. Additionally, it is used to provide ventilation during summers.
- **Solar cooking**: Solar cookers are distributed across various provinces of China, mainly rural areas where the harsh conditions and a shortage of energy resources pose difficulties for local people. Solar cookers help in cooking food, thus helping people meet a basic necessity of life [36].
- **Solar ponds and swimming pools**: Solar thermal systems can be used to maintain the temperature of ponds and swimming pools during winters.

Maintaining the water temperature can protect specific species of fish and prawns during harsh winters [36].

- **Solar drying**: This process is used to dry crops and other traditional products in China and other parts of world [36].

Solar thermal systems can considerably reduce the electricity demand. It is estimated that solar heat has the potential of providing up to 60–100 EJ/yr worldwide by the year 2050 [37].

5. PV/T Technology

The PV/T technology converts the radiation of the sun into heat and electricity simultaneously thus; increasing the overall energy efficiency of the system. The PV/T technology can be classified according to the developments made in this field.

5.1. Flat plate collectors

There is a glazed glass on the top. Under the glass, the PV cells are mounted on a metal plate which has good thermal properties and poor electrical properties. The PV cells cover 75% of the metal. The metal plate is coloured black as black surfaces absorb the most light. The cells convert the solar radiation into electricity. However, only 5-20% of the incident energy is converted to electricity, depending on the PV cell technology used. The remaining is converted into heat. The efficiency of the cells decreases as they gain more heat. The fluid in the duct absorbs heat from the cells hence improving their efficiency. Heat gained by the fluid is in turn used to provide solar water heating, space heating or other applications. The insulation at the base of the pipes/duct prevents heat loss to the ambient and the glazing above the PV cells prevents heat loss through convection. Thus, the system not only fulfils the electrical needs but also the heating purpose [38, 39]. Flat plate collectors have a good cost to performance ratio. Moreover, they have great mounting flexibility. Flat plate collectors are the most commonly used collectors [38].

5.2. Evacuated tube collectors

In an evacuated tube collector in order to reduce the heat loss to the air by convection the pipes are placed in the center of a glass that has a vacuum in its [38].

- Sun can get in through all different angles. So it has better performance.
- Even if the temperature falls very low. It will sense the low temperature and will allow some warm water to flow through it. The warm water will prevent it from frosting.

If a tube gets damaged, it is very easy to replace the tube without replacing the entire system.

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5.3. Glazed and unglazed system

The transparent glass cover above the PV cells prevents the heat loss through convection. Additionally, it protects the absorber from degradation from rain, UV radiation, storm, etc. The glass cover increases the thermal efficiency of the system. However, the optical losses increase at the air-glass interface resulting in the reflection of some solar radiation [38, 39].

Unglazed absorbers are better than glazed/insulated and unglazed/insulated if the ambient temp is higher than the temp of the input water. This is mainly due to positive convection effect. Unglazed/Insulated is the most cost effective type.

5.4. Reflector boosters

Reflector boosters increase the solar radiation on the collector area thus; increasing the overall energy efficiency of the collectors whether they are glazed or unglazed, insulated or not insulated [39].

- Boosters reduce the cell area required.
- They increase the thermal energy output of flat plate collectors.
- It is placed between the collector rows; the collectors are in parallel.

5.5. Colored absorbers

Collector thermal efficiency is the useful heat gain to the total radiation falling on the collector area [40-41]. The white colour is the most sensitive to wavelength and reflects most of it whereas; black colour has the highest transmittance-absorptance product and lowest reflectance compared to any other colour. Thus, black coloured absorbers have better thermal efficiency in comparison to other coloured absorbers [42]. Absorbers that are coloured blue or red/brown have lesser thermal efficiency and 20% more cost needs to be expended for coloured absorbers to give the same overall efficiency as black absorbers. Their efficiency can be improved by the use of glazing and boost reflectors [43].

5.6. Collector efficiency

The collector efficiency is a major factor in increasing the insolation or the ability in capturing maximised solar energy. The factors listed below affect the collector efficiency:

- An increase in wind speed reduces the efficiency of the collector as the heat loss increases due to convection [43].

- Air has poor thermal heat dissipation properties compared to water thus the overall energy efficiency is better for water based system [44].
- The efficiency of the cell can be increased by decreasing the depth of the duct [45].
- The overall thermal efficiency decreases with the increase in the length of the air duct because of less thermal energy extraction from the back surface. Due to less thermal energy extraction the PV cells get hot and electrical efficiency decreases. Additionally, as heat is not extracted thermal efficiency decreases as well [43].
- The overall thermal efficiency increases with the increase in the velocity of air in the duct. As the velocity of air increases more heat is removed. If the velocity increases considerably then the contact of air with the back surface is for a very short time and thus less heat will be removed and the overall thermal efficiency becomes constant [41, 43].

Glass-to-glass PV/T air collector has better thermal efficiency as solar radiation passes through the glass and is absorbed by the black surface [41].

5.7. Advantages and disadvantages of PV/T systems

PV/T system offers the following advantages and disadvantages:

Advantages of the PV / T system

- Greater amount of energy can be obtained by utilizing lesser area.
- The electrical efficiency and life expectancy of the PV panel is improved by cooling of PV cells.
- Greater overall energy efficiency thus; energy payback cost will be reduced.
- With respect to aesthetics, architects and consumers prefer a uniform PVT roof area to a roof area partially covered with thermal collectors and partially with PV laminates [43].

Disadvantages of PV/T Systems

PV/T systems have less thermal and electrical efficiency as compared to individual Thermal and PV systems [41].

5.8. Hybrid photovoltaic thermal (PV/T) market

In 2005, a three year research work was initiated under Task 35 of the International Energy Agency for the development and marketing of Hybrid PV/T systems in Australia. Similar work pertaining on the implementation strategy is wide-spreading across the globe in order to preserve the tourism structure. The aim was to increase the commercial competitiveness and understanding of the system [46]. In 2008, the Beijing Olympic Village had the world's first commercial hybrid solar system. Additionally, the building is home to conventional air-heating. It played a role in bringing forward the hybrid PV/T technology to the global audience [47]. Hybrid PV/T technology has been installed in organizations like US Army, NASA and Government of Canada, etc. [43].

6. Conclusions

Ecotourism offers a viable alternative option for both economic and environmental reasons for hotel and tourism industry from energy as well as a global perspective. Especially nowadays, there are advanced technologies and designs available for hybrid photovoltaic thermal (PV/T) systems to meet the specific demands and characteristics of the tourism facilities. By focusing on the irreplaceable qualities of the surrounding natural environment and practicing to the fullest extent of the principles of ecotourism, PV/T systems are able to replace the conventional electricity generating systems with the benefits of long-term viability and optimal use of good sunshine in the region of the tourist area.

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