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Solar Airports

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Abstract

Building-integrated photovoltaics (BIPV) is the fastest-growing segment of the photovoltaic market worldwide. The integration of PV solar modules to airport buildings is one of the most ideal BIPV applications. Airport building electrical power loads are driven mainly by air-conditioning and lighting. There is usually a good match between air-conditioning loads and PV generator maximum output. In this study, the passenger traffic and the energy demand in the world's largest airports are reviewed, and the space requirements for PV installations at the airports are analyzed. It is concluded that the airport terminals can be one of the most cost effective ways of producing electricity through the use of renewable energy.

Introduction

The world is facing real challenges concerning the future of energy. Global warming and rising energy costs are making our societies and economies vulnerable. These challenges require a comprehensive and ambitious response. In the complex picture of energy policy, the renewable energy sector is one that stands out in terms of its ability to reduce greenhouse gas emissions and pollution, utilize local and decentralized energy sources, and stimulate world-class, high-tech industries.

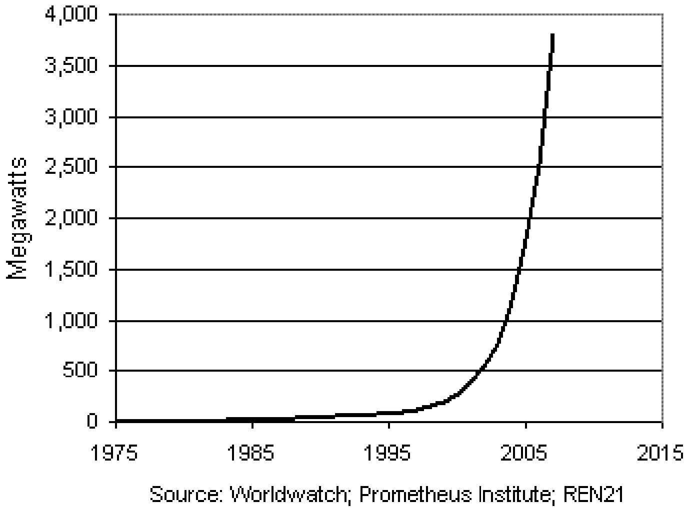
Record oil prices and speculations of when oil prices will exceed $100 per barrel have become a reality. Because of these unusually rapid increases in oil prices, many nations have shifted their focus to more abundant fossil energy resources, such as gas and coal. However, utilization of fossil energy resources, such as coal, will present a substantial increase in greenhouse gas emissions and air pollution.

Photovoltaics (PV) is a key technology that has proven to be one of the most reliable and cleanest renewable energy technologies. PV and other renewable energy technologies are the only ones that offer reduction in energy prices and greenhouse emissions.

Photovoltaic Industry

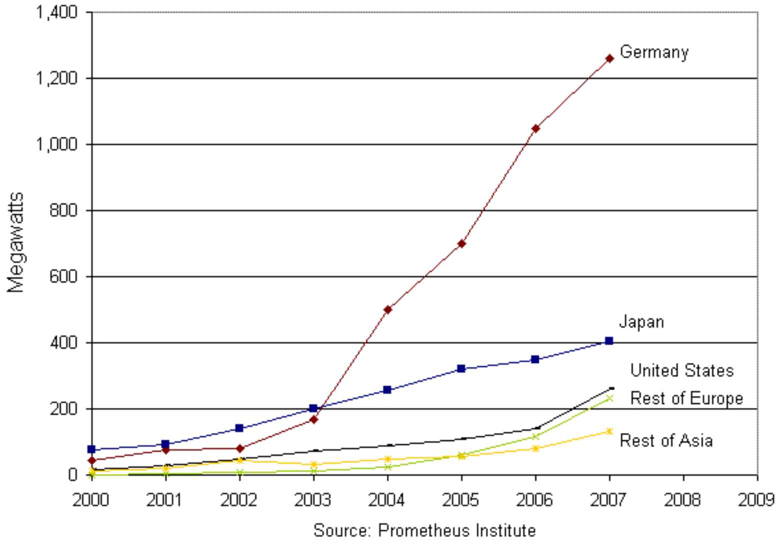
Since 2000, PV energy has been one of the most rapidly growing renewable energy sectors around the world. During the past seven years, the average growth rate of PV was more than 40 percent. World solar PV market installations reached a record high of 2,826 megawatts (MW) in 2007, representing a growth of 62 percent more than the previous year.

Figure 1 shows the worldwide growth of PV industry between 1975 and 2007. Production of PV jumped to 3,800 MW worldwide in 2007, which represents an increase of 50 percent over 2006. At the end of 2007, cumulative global production



Source: Worldwatch; Prometheus Institute; REN21

Figure 1. World Annual PV Production, 1975–2007



Source: Prometheus Institute

Figure 2. Annual PV Installations in Select Countries and Regions, 2000–2007

stood at 12,400 MW, enough to power 2.4 million U.S. homes. Growing by an impressive average of 48 percent each year since 2002, PV production has been doubling every two years, making it the world's fastest growing energy source.

Figure 2 shows that Germany's PV market reached 1,328 MW in 2007 and currently accounts for 47 percent of the world market. During the same time, Spain soared over 480 percent to 640 MW, while the United States increased by 57 percent to 220 MW.

The growth in installations in the United States increased from 20 percent in 2005 to 31 percent in 2006, primarily driven by California and New Jersey. The California Solar Initiative was launched in January 2006, as part of the state's Million Solar Roofs program, to provide more than $3 billion in incentives for solar power. The goal is to generate 3,000 MW of new solar power statewide by 2017. New Jersey's Clean Energy Rebate Program, which began in 2001, offered a rebate of up to $3.50 per watt for residential PV systems, more than tripling installations between 2005 and 2006. Other states, such as Maryland, have passed renewable portfolio standards that mandate a certain percent of electricity generation from solar PV. For Maryland, the goal of producing 2 percent of electricity from the sun by 2022 is expected to lead to 1,500 MW of PV installations in the state.

Among the three largest PV markets in the world, the European Union (EU) reached its 2010 White Book target of 3 GW capacity in 2006. From 2001 to 2006, the EU showed an average annual increase of 50 percent in PV installations. With an average annual 35 percent increase in PV installations, the EU is expected to exceed 11 GW, and with a 45 percent growth, the cumulative PV installations in the EU will exceed 15 GW capacity. (See Figure 3.)

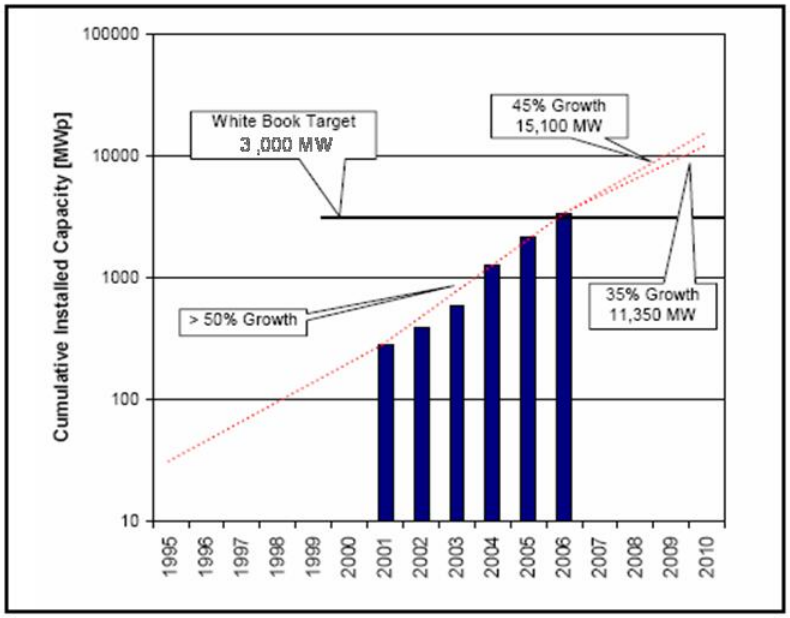


Figure 3. European Union Cumulative Installed PV Capacity [1]

Figures 4 and 5 show the cumulative installed PV capacity in Japan and the United States. It is expected that Japan will reach a cumulative capacity of about 3 GW in 2010 with the current growth rate. The United States will reach a cumulative capacity of approximately 1.5 GW with its existing growth rate, which will be below the Million Solar Roofs target of 3.5 GW.

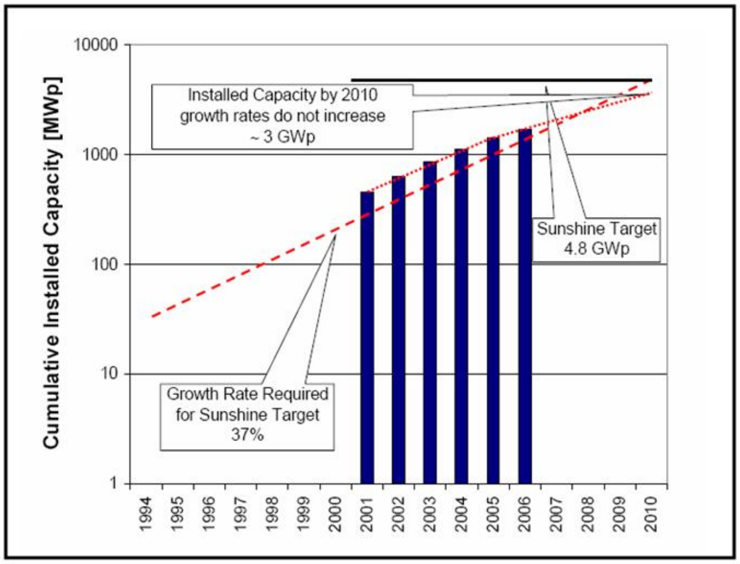


Figure 4. Cumulative Installed PV Capacity in Japan [1]

One of the reasons for the PV installation growth rate in the United States being too low to reach the One Million Solar Roof Target is the lack of large-scale PV installations. Meanwhile, Germany, Spain, and Portugal have been installing numerous PV systems with more than 20 MW capacities. Due to these efforts, the EU is expected to reach a cumulative PV capacity that will be three to four times greater than the target levels planned for 2010. It has been proven by the large scale PV installations that as the capacity of an installation goes higher, the unit cost of a PV system becomes lower. To achieve a successful PV market transformation, the United States must invest in large-scale PV applications, such as PV farms and building integrated PV (BIPV).

Currently, there are few incentives to promote large scale PV installations in the United States. With lack of incentives for investment in large scale PV installations, there are only two options to achieve a high growth rate:

1. Large scale PV installations (PV farms) by the utility companies.
2. Large scale PV applications at the airports as BIPV (terminal buildings), roof top PV (terminal buildings), and PV farms (parking lots and other restricted areas such as airport approach zones).

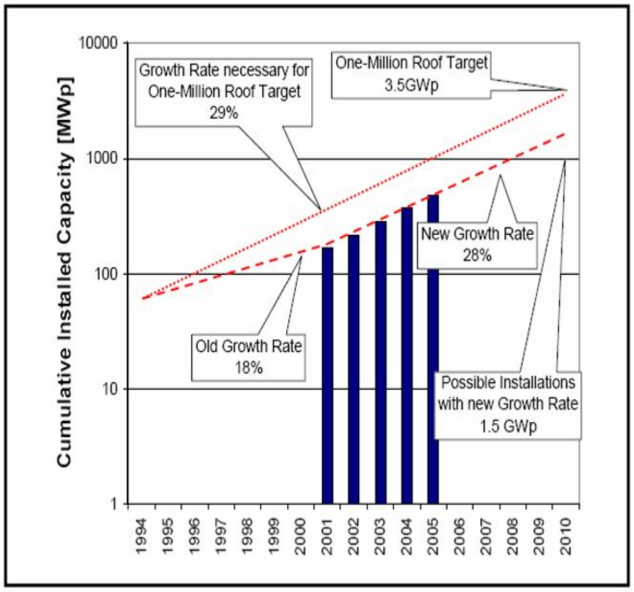


Figure 5. Cumulative Installed PV Capacity in the United States [1]

Large-Scale PV Installations by Utility Companies

Large-scale PV power plants, which consist of many PV arrays working together, can be useful to utilities in a variety of ways. However, many utilities do not want to build PV plants (PV farms), and there are several reasons. For example, using current utility accounting practices, PV-generated electricity still costs more than electricity generated by conventional plants in most places, and regulatory agencies require most utilities to supply the lowest cost electricity. Furthermore, PV systems produce power only during daylight hours, and their output can vary with the weather. Utility planners must, therefore, treat a PV power plant differently than they would treat a conventional plant.

Despite these obstacles, more utilities are becoming involved in PV power. For example, DOE, the Electric Power Research Institute, and several utilities have formed a joint venture called Photovoltaics for Utility-Scale Applications (PVUSA). This project operates three pilot test stations in different parts of the country for utility-scale PV systems. The pilot projects allow utilities to experiment with newly developing PV technologies with little financial risk.

In another experiment, utilities are exploring connecting PV systems to the utility grid in places where they have a higher value. For example, adding PV generation near the places where the electricity is used prevents the energy losses associated with sending electric currents long distances through conventional power lines. This means the PV system is worth more to the utility when it can be placed near the customer.

PV systems could also be installed at places in utility distribution system service areas where the population is increasing rapidly. In these places, using PV systems could eliminate a utility's need to increase the size of power lines, as well as entire servicing areas. Installing PV systems near other utility distribution equipment, such as substations, can also prevent overloading of the equipment in the substation.

Building Integrated Photovoltaics (BIPV) Applications and Solar Airports

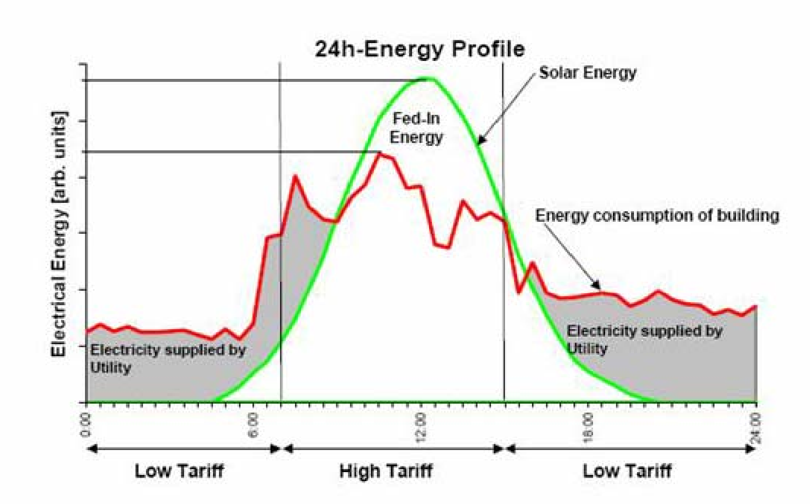
The most promising application of large-scale PV installations will be in BIPV systems installed at the airports.

BIPV is the fastest-growing segment of the PV market worldwide. The integration of PV solar modules to airport terminals is an ideal BIPV application. Airport buildings are typically large, isolated, mostly low-rise structures with little or no shading, where there is plenty of room to accommodate PV modules on rooftops, façades, and parking lots.

The first BIPV at a U.S. airport terminal was installed at FedEx in Sacramento, California, in 2005. This 1 MW PV system produces the equivalent of power used by more than 900 homes, meeting more than 80 percent of the hub facility’s peak energy demand. Following the FedEx PV installation, a 500 kW PV array at San Francisco International airport was completed. Installation of a 2 MW PV system at Denver International Airport and a 2 MW PV solar system at Fresno Yosemite International Airport will be completed before the end of 2008. At Fresno Yosemite International Airport, five acres of raised solar panels will be used to create shade for rental car lots, and 20 acres of ground-mounted PV arrays. These PV arrays have been approved by the FAA for installation in a portion of the airport’s approach zone, where the occupied structures are not allowed.

At low latitudes, building rooftop integration of PV is a common application of BIPV. At high latitudes, airport buildings can feature PV modules on vertical façades and curtain walls, which make the best use of the lower sun at these sites. Airport grounds are usually large enough to accommodate free-standing PV arrays that can be used in some cases as noise-barriers to deflect aircraft noise from passenger terminals. Airport building electrical power loads are driven mainly by air-conditioning and lighting, and there is usually a good match between air-conditioning and lighting loads and PV generator maximum output. Figure 6 shows how peak electricity consumption can be met mostly by solar energy, while off-peak demand is met by the energy supplied by the utility.

Because of the large differences in energy demand among airports, an individual feasibility study should be performed for each case study with the specific requirements of that locality. Energy demand in airports can widely vary year by year, depending on the variations in the number of passengers and addition of new facilities. Most airports are growing much faster than the economy as a whole; this requires large efforts to forecast demand and frequent increases in the energy supply as well. Another important aspect when sizing the PV capacity is the shape of energy demand profiles. An energy profile with very little fluctuation (see Figure 7) throughout the year may require an oversized PV capacity.



Source: RWE/Schott Solar

Figure 6. Daily Profile of Solar Energy Production and Energy Consumption of a Building

The electric demand for a large airport usually follows the pattern shown in Figure 7. Because the passenger traffic remains high throughout the year, the monthly demand for electricity remains constant with little or no seasonal fluctuation. Since the PV panels produce the most electricity during the summer months, the demand for electricity by large airports in the summer will have a good match with PV capacity. However, PV capacity during the winter months will not match with the electric demand of large airports unless the PV system is oversized.

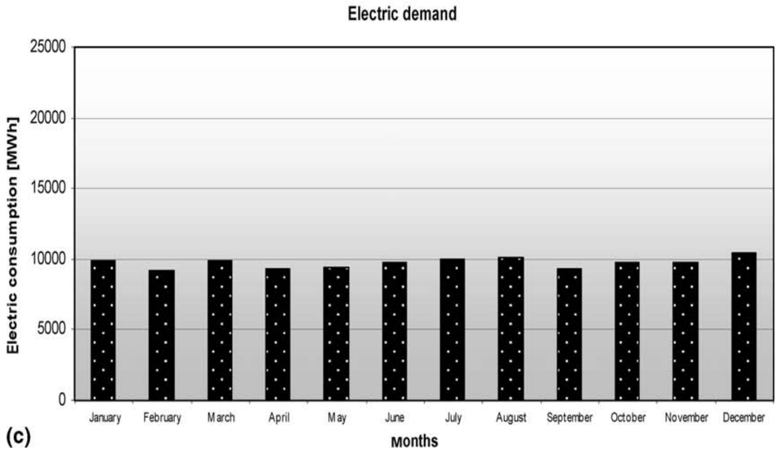


Figure 7. Electric Demand for a Large Airport [2]

If net-metering is applicable, it makes sense to oversize the PV system, feed the excess amount of electricity to the utility grid during the summer months, and use the electric credit during the winter months.

In Figures 8(a) and 8(b), the passenger traffic in six airports worldwide is presented. Figure 8(a) includes large international airports with more than 25 million passengers per year, and Figure 8(b) shows smaller airports with less than 11 million passengers per year. As evident, the traffic trends of large airports are more regular, while large fluctuations can be observed in the small airports due to the influence of seasonal tourism. This suggests that smaller airports with large fluctuations between the tourism season and off-season can benefit from the installation of PV systems more than the larger airports. Typically during May through September, the demand for electricity is higher when the largest portion of the airport passenger traffic will be observed. At the same time, the highest level of solar electric demand will be produced during those months when the passenger traffic is highest. In small airports, it is not necessary to oversize the PV system.

The top 30 international airports with the highest passenger traffic, varying from 33,000,000 to 90,000,000 passengers per year, are listed in Table 1. These airports occupy and consume huge areas of land mass, creating massive urban heat islands of impermeable, hot surfaces. For example, the area of roofs and pavement at the Atlanta Hartsfield-Jackson International Airport (ATL) is estimated at more than 70,500,000 square feet, or 1619 acres. Assuming that 25 percent of these roofs and paved surfaces (parking lots) can be utilized for the installation of PV arrays, ATL can offer enough space to install a PV system with a 1.50 GW capacity. Of course, the cost of such a large capacity would not allow the installation of that magnitude. Since 2003, large-scale PV systems, with capacities varying from 5 MW to 20 MW, have been installed in many parts of Spain and Germany.

Similar systems can be installed in all airports by creating funds through airport taxes. If each passenger ticket included has a $1 surcharge, ATL would collect $90,000,000 annually. Assuming the cost of 1 KW PV array is approximately $9,000, this revenue could be used to install PV arrays on a continuous basis. Figures 9 and 10 show the airport traffic at ATL over a 10-year period with an annual passenger traffic increase of 3 percent. A typical peak load for ATL is estimated at 75 MW.

This example shows that if a $1 surcharge is collected from each passenger, the revenue from this source would allow a large airport, such as Atlanta (ATL), to install a 120 MW PV system over a period of 10 years. During this 10 year period, total accumulated PV capacity could exceed the peak load of ATL.

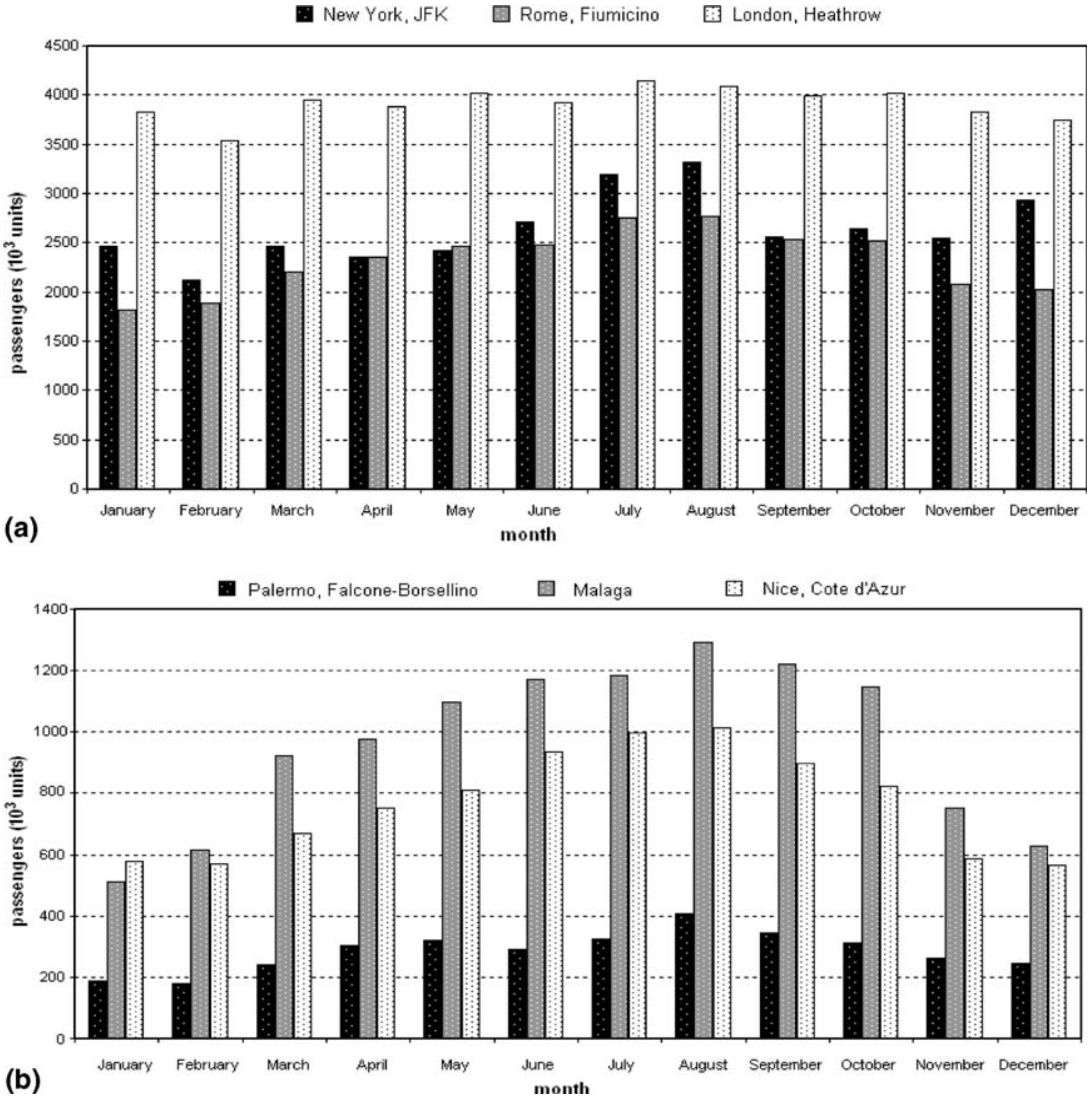


Figure 8 – Passenger Traffic in Large and Small Airports [2]

(a) Passenger Traffic in three large airports (New York, JFK; Rome, Fiumicino; and London, Heathrow)

(b)Passenger traffic in three small airports (Palermo, Malaga and Nice, Cote d'Azur)

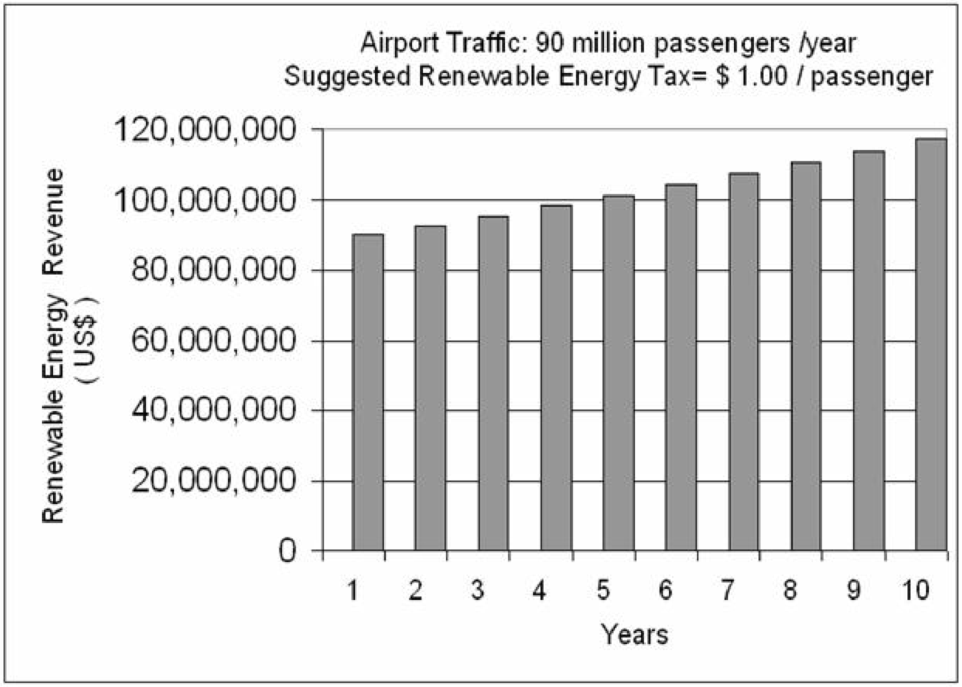


Figure 9. Renewable Energy Revenue Accumulated by a Large Airport

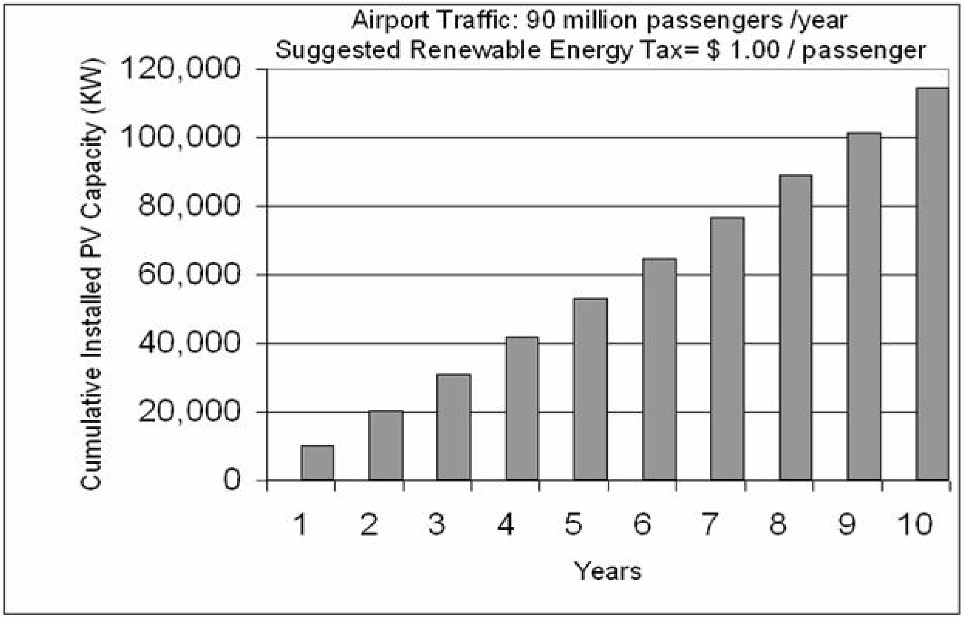


Figure 10. Cumulative Installed PV Capacity over a 10-year Period

Table 1. Top 30 International Airports (Based on Passenger Traffic)

Rank	Airport	Total Passengers (2007)
1.	**Hartsfield-Jackson Atlanta International Airport**	89,400,000
2.	**O'Hare International Airport**	76,200,000
3.	London Heathrow Airport, United Kingdom	**67,900,000**
4.	Tokyo International Airport, Japan	**61,283,502**
5.	**Los Angeles International Airport**	61,900,000
6.	Charles de Gaulle International Airport, France	**59,900,000**
7.	**Dallas-Fort Worth International Airport**	59,800,000
8.	Frankfurt Airport, Germany	**54,200,000**
9.	Beijing Capital International Airport, People's Republic of China	**53,600,000**
10.	Madrid Barajas International Airport, Spain	**52,100,000**
11.	**Denver International Airport**	49,900,000
12.	Amsterdam Airport Schiphol, The Netherlands	**48,800,000**
13.	**John F. Kennedy International Airport**	49,000,000
14.	**McCarran International Airport**	47,700,000
15.	Hong Kong International Airport, People's Republic of China	**47,800,000**
16.	**George Bush Intercontinental Airport**	43,000,000
17.	**Phoenix Sky Harbor International Airport**	42,200,000
18.	Suvarnabhumi Airport, Thailand	**41,200,000**
19.	**Newark Liberty International Airport**	37,400,000
20.	**Orlando International Airport**	36,500,000
21.	**Detroit Metropolitan Wayne County Airport**	36,000,000
22.	Singapore Changi Airport, Singapore	**36,700,000**
23.	**San Francisco International Airport**	35,800,000
24.	London Gatwick Airport, United Kingdom	**35,200,000**
25.	Narita International Airport. Japan	**35,600,000**
26.	**Minneapolis-Saint Paul International Airport**	35,200,000
27.	Munich Airport, Germany	**34,000,000**
28.	Dubai International Airport, United Arab Emirates	**34,300,000**
29.	**Miami International Airport**	33,700,000
30.	**Charlotte/Douglas International Airport**	33,200,000

Conclusions

In this work, the economic feasibility of large-scale BIPV installations at small and large airports was explored. Since the airports are typically shade-free structures, it is very attractive to install PV panels where the system will work more efficiently without a shading factor than any other solar PV applications.

Airports are visited by millions of people each year, presenting a perfect platform for PV in terms of available energy resources and for raising awareness of the technology with the public.

Airports consume large amounts of electricity, and installing the solar panels directly next to the terminals will cut down the power transmission losses.

Using a polluter-pays approach, levying passengers through a surcharge in airport departure taxes can straightforwardly finance BIPV systems in airports. This surcharge would be enough to make all airports 100 percent solar worldwide in a period of 10 to 15 years without the need for any external funding. Considering worldwide 4.2 billion air passenger traffic, if such surcharge existed, $4.2 billion (U.S.) of a renewable energy fund could be created annually. The potential is huge and could trigger the economies of scale that PV is still lacking to become mainstream.

References

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Biography

Serdar Z. Elgun received his B.S. in Mechanical Engineering from the Aegean University of Izmir, Turkey, in 1977, and his M.S. in Mechanical Engineering from Mississippi State University in 1981, where he worked on “Thermal Gradient Solar Pond” and “Off-peak Energy Storage in Phase Change Materials” projects funded by Tennessee Valley Authority (TVA). Between 1981 and 1982, he attended the graduate program in New Mexico State University and worked on “Thermal Storage of Solar Energy” projects. Between 1992 and 1996, he also attended the graduate program in the Material Science Engineering department at Stony Brook University and conducted research on “Crack Propagation through PS and PMMA Interface due to Impact.” In 1982, he joined the Mechanical Engineering Technology department of Farmingdale State College. Currently, he is a professor at Farmingdale State College of New York, serving as a Department Chair since 2005. He is an active member of the Farmingdale Solar Energy Center serving in various capacities since its inception in 2000. He developed the Mechanical Engineering Technology B.S. program, the Facility Management B.S. program, and five online courses that have been offered through Suny Learning Network (SLN). He is a member of the American Society of Mechanical Engineers (ASME) and American Society of Engineering Education (ASEE).

Kamal Shahrabi received a B.S. in Electrical Engineering from New Jersey Institute of Technology, Newark, NJ, in 1983; an M.E. in Electrical Engineering from City College in New York, New York, NY, in 1985; and an M. Phil. and Ph.D. in Electrical Engineering from City University Of New York, New York, NY, in 1992. Kamal Shahrabi is a Dean of the School of Engineering Technologies and Professor in the Department of Electrical and Computer Engineering Technology. He has been a Professor in the Technology Department at Kean University of New Jersey since 1986–2007 and has been a Chairperson of the department since September 1998. Dr. Shahrabi has published several papers in various areas of communication, robot tracking in space, wireless communication, impact of globalization of advanced telecommunication technologies in developing countries, high speed optical satellite communication, and femtosecond pulse shaping. Dr. Shahrabi has several years of experience in the areas of digital signal processing, space tracking, communication, and satellite control systems, while conducting research at the City University of New York for NASA.

In addition, he has worked as a Visiting Professor in the Electrical Engineering Department with Institut Teknologi Tun Hussein Onn, Parit Raja, Batu Pahat, Johor, Malaysia, and he developed an engineering curriculum, with DSP specialization, for the institute (ITHO) during his stay.

His research interests are in the fields of digital signal processing algorithms, spread spectrum, nanotechnology, and wireless communication systems.