SOLAR AIRPORTS

A Future Multi-billion Euro PV Market?

Airports are typically large, isolated, shade-free structures that are visited by millions of people every year presenting the perfect platform for PV both in terms of available solar resource and for awareness raising of the technology with the public. Ricardo Ruther and Priscila Braun present the case for PV integration on airport buildings and airport grounds worldwide and argue that it could become a multi-billion euro market for solar PV.

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 buildings are typically large, isolated, mostly low-rise structures free of shading, with plenty of room to accommodate PV modules on rooftops and façades.

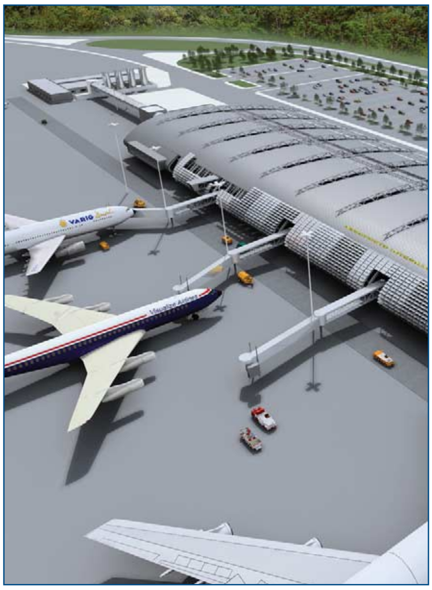

Figure 1: The project of the new Florianopolis International Airport in Brazil is ideal for incorporating PV on both the brise-soleil surfaces as well as on the smoothly-curved and slightly-tiled roof-cover

At low latitudes, where the sun is always high in the sky, the small slopes of airport building roof covers, like the one shown in Figure 1, favour roof-top integration of PV; high latitude airport buildings can feature PV modules on vertical façades and curtain walls, to make the best use of the lower sun at these sites. Airport building envelopes often make use of *brise-soleil* surfaces to avoid direct solar radiation, and these can double as PV-active surfaces at both high and low latitudes. Furthermore, airport grounds are usually large enough to accommodate free-standing PV arrays which can be used in some cases also as noise-barriers to deflect aircraft noise from passenger terminals. Airport building electrical power loads are driven mainly by air-conditioning, and there is usually a good match between air-conditioning loads and PV generator maximum output.

Power demands and PV potential

Figure 2 shows the passenger terminal and an aerial view of the Orlando (USA) Airport, the destination of many International Solar Energy Society (ISES) members who will attend the 2005 ISES Solar World Congress in August. Typical airport buildings and airport grounds are usually so vast, that supplying 100% of their electricity loads with PV would not be a difficult task to accomplish, as far as suitable area availability is concerned.

We have studied the 66 public airports in Brazil, the spread of their 83 million passengers in 2004, and their annual power demands vs. solar radiation levels, as well as their buildings and ground space availability. For most of these airports, the full supply of their total annual electricity demands with PV would require some 1 to 5% of the respective airport available and suitable ground areas. Rack-mounted PV arrays on airport grounds are more versatile in terms of tilt and orientation, and in some cases will be a more interesting option to optimise PV output when compared with BIPV. The Saarbrücken airport in Germany (Figure 3) has operated a 1.4 MWp, ground-mounted, grid-connected PV system since January 2004, with an extra 2.2 MWp to be

Author information
Profesor Ricardo Rüther is based at the LABSOLAR - Laboratório de Energia Solar and the LabEEE - Laboratório de Eficiência Energética em Edificações. He is also ISES do Brasil President. Priscila Braun is based at LabEEE - Laboratório de Eficiência Energética em Edificações.
Contact: Profesor Ricardo Rüther, Universidade Federal de Santa Catarina / UFSC, Caixa Postal 476, Florianópolis - SC, 88040-900, Brazil. Tel.: +55 48 331 5174; Fax: +55 48 331 7615; Email: ruther@mbox1.ufsc.br

installed by August 2005 [1]. In some cases, like in the newly proposed Florianopolis Airport shown in Figure 1, virtually all of the 1.3 MWp required to supply its current electricity demands could be integrated onto the building's envelope. To supply the 400 GWh demanded by the 66 Brazilian public airports in 2004, some 250 MWp of photovoltaics would have to be installed.

Global warming

Air travel contributes a great deal to global warming. Aviation exhaust gases presently generate 3.5% of global emissions, and their contribution is expected to double in the next 15 years [2]. Airports throughout the world are constantly being expanded and upgraded, and the recent take off of the first Airbus A380 consolidates the growing trend. Airbus estimates a potential market for over 1200 such airplanes until 2020, with over 4.6 million flights [3].

When delegates of the 2005 ISES Solar World Congress convene in Orlando in August to celebrate the 50 years of the International Solar Energy Society, the

Figure 2: Aerial View of Orlando International Airport (USA) and Terminal B (inset) showing the vast areas available for PV integration on both terminals and grounds

Table 1: CO_2 emissions and equivalent carbon-trading market price of single-passanger travel to Orlando,USA (MCO)

From - City (Airport)	tCO_2	€
Singapore, SGP (SIN)	6.32	151.81
Bangkok, THA (BKK)	5.74	137.87
Sydney, AUS (SYD)	5.29	127.09
Hong Kong, CHN (HKG)	5.14	123.46
New Dehli, IND (DEL)	4.82	115.78
Joahnnesburg, ZAF (JNB)	4.78	114.82
Harare, ZWE (HRE)	4.75	114.10
Shangai, CHN (SHA)	4.70	112.89
Beijing, CHN (PEK)	4.42	106.17
Tokyo, JPN (NRT)	4.24	101.84
Tel Aviv, ISR (TLV)	3.81	91.52
Cairo, EGY (CAI)	3.75	90.08
Athens, GRC (ATH)	3.36	80.71
Budapest, HUN (BUD)	3.05	73.26
Vienna, AUT (VIE)	2.97	71.34
Rome, ITA (FCO)	2.97	71.34
Prague, CZE (PRG)	2.89	69.42
Berlin, DEU (TXL)	2.68	64.37
Stockolm, PNG (SMP)	2.67	64.13
Zurich, DEU (ZHR)	2.64	63.41
Copenhagen, DNK (CPH)	2.62	62.93
Frankfurt, DEU (FRA)	2.61	62.69
Buenos Aires, ARG (EZE)	2.54	61.01
Oslo, NOR (TRF)	2.53	60.77
Brussels, BEL (BRU)	2.50	60.05
Amsterdam, DEU (MAS)	2.49	59.81
Paris, FRA (ORY)	2.47	59.33
Florianópolis, BRA (FLN)	2.45	58.85
Rio de Janeiro, BRA (SDU)	2.40	57.65
Madrid, ESP (MAD)	2.40	57.65
Santiago, CHL (SCL)	2.39	57.41
London, GBR (LHR)	2.38	57.17
São Paulo, BRA (GRU)	2.34	56.45
Seattle, USA (SEA)	1.06	25.46
San Francisco, USA (SFO)	1.01	24.26
Los Angels, USA (LAX)	0.91	21.86
Phoenix, USA (PHX)	0.76	18.26
Denver, USA (DEN)	0.56	13.45
Minneapolis, USA (MSP)	0.47	11.29
México, MEX (NLD)	0.39	9.37
Toronto, CSN (YBZ)	0.37	8.89
Philadelphia, USA (PHL)	0.36	8.65
Houston, USA (IAH)	0.35	8.41
Chicago, USA (ORD)	0.35	8.41
Detroit, USA (DET)	0.34	8.17
Dallas, USA (DFW)	0.34	8.17
Washington, USA (WSG)	0.33	7.93
New York, USA (EWR)	0.33	7.93
Atlanta, USA (ATL)	0.16	3.84
Miami, USA (MIA)	0.07	1.68

Table 2: Top 30 Airports in passenger numbers

Rank	City (Airport)	Total passenger 2004	% Change from 2003
1	Atlanta, GA (ATL)	83,578,906	5.7
2	Chicago, IL (ORD)	75,373,888	8.7
3	London, GB (LHR)	67,343,960	6.1
4	Tokyo, JP (HND)	62,320,968	(0.9)
5	Los Angeles, CA (LAX)	60,710,830	10.4
6	Dallas, TX (DFW)	59,412,217	11.6
7	Frankfurt, DE (FRA)	51,098,271	6.3
8	Paris, FR (CDG)	50,860,561	5.7
9	Amsterdam, NL (AMS)	42,541,180	6.5
10	Denver, CO (DEN)	42,393,693	13.0
11	Las Vegas, NV (LAS)	41,436,571	14.3
12	Phoenix, AZ (PHX)	39,493,519	5.5
13	Madrid, ES (MAD)	38,525,899	7.5
14	Bangkok, TH (BKK)	37,960,169	25.8
15	New York, NY (JFK)	37,362,010	17.7
16	Minneapolis, MN (MSP)	36,748,577	10.7
17	Hong Kong, CN (HKG)	36,713,000	36.1
18	Houston, TX (IAH)	36,490,828	6.8
19	Detroit, MI (DTW)	35,199,307	7.8
20	Beijing, CN (PEK)	34,883,190	43.2
21	San Francisco, CA (SFO)	33,497,084	14.3
22	Newark, NJ (EWR)	31,847,280	8.1
23	London, GB (LGW)	31,461,523	4.8
24	Orlando, FL (MCO)	31,110,852	13.9
25	Tokyo, JP (NRT)	31,106,264	17.2
26	Singapore, SG (SIN)	30,353,565	23.1
27	Miami, FL (MIA)	30,156,727	1.9
28	Seattle, WA (SEA)	28,703,352	7.2
29	Toronto, CA (YYZ)	28,655,526	15.8
30	Philadelphia, PA (PHL)	28,508,510	15.6

Source: ACI - Airports Council International [8]

invention of the photovoltaic solar cell, and to report on their latest research findings on clean and renewable energy technologies, each delegate will be responsible for a considerable amount of greenhouse gas emissions. Table 1 shows the impressive amounts of per passenger/flight CO_2 emissions for flights from various airports to Orlando, calculated using the Atmosfair Emissions Calculator [4] and the equivalent carbon-trading market value at current prices [5]. In fact, some 95% of the greenhouse gas emissions related to the Conference will be due to air travel [6]. Alternative aviation fuels, with a carbon neutral or lower CO_2 emissions content, have been under investigation for some time, but higher costs, lower energy contents and thermal instability have prevented their uptake so far [7].

Who pays the bill?

Perhaps the most impressive figure, and the one from which the widespread application of PV technology could benefit most, is the amount of passengers taking off on airplanes from airports all around the globe every year. In 2004, over 3.7 billion passengers flew from the 1530 Airports Council International (ACI) -registered airports worldwide [8]. The ACI operates in 175 countries, and expects a 5% annual growth rate on these figures. The Intergovernmental Panel on Climate Change (IPCC) forecasts considerable growth rates for air services in developing countries with industrialised bases from 2015 [9]. Table 2 shows the 30 busiest airports worldwide, and the annual growth in passenger numbers from 2003.

Virtually "half of the world" travels by air

Figure 3: Saarbrucken Airport (Germany) showing the 1.4MWp ground-mounted PV installation operating since 2004

every year, including most of our world decision-makers; this makes airport buildings a perfect place to showcase PV technology, and at the same time mitigate the effects of burning fossil fuels to generate the electricity to run these buildings. Using a polluter-pays approach, levying passengers through a surcharge in airport departure taxes can straightforwardly finance BIPV in airports. A surcharge corresponding to a fraction of the carbon equivalent presented in Table 1 would be enough to solarise each and every airport worldwide. The potential is huge and could trigger the economies of scale that PV is still lacking in order to become mainstream. Furthermore, this application generates a demand for large amounts of PV modules scattered over the globe, enabling the establishment of PV module production plants in many of the participating countries, and the so long-awaited price reductions that result from economies of scale, which will in turn benefit the estimated two billion people which do not have access to electricity worldwide.

Going back to our study case Brazil, at a total installed PV system cost of Euro 6/Wp, and using year 2004 total passenger numbers and airport energy consumption, a Euro 2 surcharge per passenger/flight would generate enough revenue to install the 250 MWp previously mentioned and make all Brazilian airports 100% solar in 10 years. This initial approach is conservative and will be further refined, as annual passenger numbers growth for the next 10 years, and the associated compound increase in surcharge collection, is expected to be larger than airport annual energy demand growth. The increasing annual airport electricity savings in utility bills with the gradual increase of PV penetration every year have not been accounted for in the present analysis either. PV systems prices are also expected to decline with larger volumes, bringing further benefits to the economics of this approach. Furthermore, this annual demand would justify the still lacking market volumes necessary to attract industries to establish a PV module manufacturing plant in the country. With a 25 MWp-per-year-and-growing guaranteed demand for 10 years for PV in airports alone, there is reasonable volume to justify local production. In this particular case, producing PV modules in a country like Brazil, where the electricity mix is dominated by hydropower generation, would bring the extra benefit of making PV modules greener [10]. The worldwide potential of this concept is much larger, as we will further demonstrate.

We have also compared air travel emissions with the carbon mitigation effect of installing PV in airports instead of burning fossil fuels in conventional generation units to generate electricity for airports where these flights take off. The avoided emissions amount to some 250,000 tons of CO_2-equivalent per year for the Brazilian study case, considering the typical coal-fired units operating in some parts of the country. At current carbon trading market prices, this amounts to some Euro 6 million per year [5]. Impressive as these figures might seem, in terms of air travel equivalent, however, the avoided emissions correspond to some 3.5 million Rio de Janeiro to São Paulo air shuttle passenger/trips per year, in a country where nearly 83 million passenger/trips take off annually.

Grid-connection issues

Grid interfacing of PV systems is not necessarily a common practice in a considerable fraction of the countries this project is aiming at, and concerted efforts by the local PV communities in these countries will be required to develop and implement the requirements involved in such a project. ISES

National Offices should play a major role in promoting these actions. Most of the countries with ACI-registered airports have a national section of ISES, and a proposition like this will require an organisation with the technical expertise and the political outreach and status of ISES to be carried out.

Outlook

The polluter-pays approach used in this study is presented in contrast to the various PV financing, incentive and subsidy models currently in place in different countries worldwide, where sometimes less privileged sectors of a given society are obliged to contribute to something that will compensate damages not caused by them, or which will not necessarily revert in a direct benefit to them. In the present case there is not such conflict, as there is direct relation between emissions liability and contribution to emissions mitigation. Extending this proposed 2 Euros per passenger/trip levy to all the ACI-registered airports worldwide, would generate funds in excess of 7 billion Euros per year for installing PV in airports alone. In 2004, the total global PV market represented some 6 billion Euros [11]! A number of air travel emission compensations through carbon offset project schemes have been proposed [12, 13], but their voluntary nature limits their outreach.

This study was initially carried out for all airports in Brazil, and will now be extended to all the ACI-registered airports in the world. The project will be presented by ISES do Brasil to ISES in Orlando, during the forthcoming 2005 ISES Solar World Congress, in August 2005, to be launched as an international project, to be carried out worldwide through all ISES National and Regional Offices.

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