Solar Airports

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The integration of photovoltaic (PV) solar modules to airport buildings is one of the most ideal building-integrated photovoltaics (BIPV) applications. Airport buildings are typically large, isolated, mostly low-rise structures free of shading, with plenty of room to accommodate PV modules on roof-tops and façades. 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, favor 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.

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

In this paper we present a study making the case for PV integration on airport buildings and airport grounds worldwide, and demonstrate how this could enable a GWp/year-scale market. We show how this concept can guarantee the volumes required to attract the necessary investments for this industry and technology to finally become established and mainstream. We also discuss the necessary policies to support this market-segment introduction in the light of carbon trading.

Airport building power demands and PV potential

Figure 2 shows the passenger terminal and an aerial view of the Rio de Janeiro Airport, the gateway airport to many Rio 6 delegates. 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.

Figure 2: The Rio de Janeiro International Airport in Brazil, is well suited for PV integration on both passenger terminal and grounds.

We have studied the 66 public airports in Brazil, the spread of their 96 million passengers in 2005, 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. The Saarbrücken airport in Germany operates a 4 MWp, ground-mounted, grid-connected PV system since January 2004 [1], which covers only a fraction of the available, allowable and suitable area. In some cases, like in the newly proposed Florianopolis (Brazil) Airport shown in Figure 1, virtually all of the 1.5 MWp required to supply its electricity demands could be integrated onto the building's envelope. To supply the 420 GWh demanded by the 66 Brazilian public airports in 2005, some 275 MWp of photovoltaics would have to be installed.

Global warming

Air travel also 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].

Table 1: CO_2 emissions and equivalent carbon-trading market price of single-passenger travel do Rio de Janeiro.

From - City (Airport)	tCO_2	€
Bangkok, THA (BKK)	8,42	226,92
New Dehli, IND (DEL)	8,27	222,88
Hong Kong, CHN (HKG)	7,82	210,75
Singapore, SGP (SIN)	7,37	198,62
Shangai, CHN (SHA)	7,37	198,62
Stockolm, PNG (SMR)	7,31	197,00
Beijing, CHN (PEK)	7,23	194,85
Tokyo, JPN (NRT)	6,76	182,18
Sydney, AUS (SYD)	4,85	130,71
Seattle, USA (SEA)	3,95	106,45
Tel Aviv, ISR (TLV)	3,85	103,76
Oslo, NOR (TRF)	3,83	103,22
San Francisco, USA (SFO)	3,78	101,87
Copenhagen, DNK (CPH)	3,78	101,87
Budapest, HUN (BUD)	3,72	100,25
Cairo, EGY (CAI)	3,70	99,72
Vienna, AUT (VIE)	3,67	98,91
Prague, CZE (PRG)	3,67	98,91
Athenas, GRC (ATH)	3,63	97,83
Los Angels, USA (LAX)	3,59	96,75
Frankfurt, DEU (FRA)	3,55	95,67
Amsterdam, DEU (AMS)	3,54	95,40
Brussels, BEL (BRU)	3,50	94,33
Zurich, DEU (ZHR)	3,48	93,79
London, GBR (LHR)	3,43	92,44
Rome, ITA (FCO)	3,42	92,17
Paris, FRA (ORY)	3,40	91,63
Phonix, USA (PHX)	3,39	91,36
Denver, USA (DEN)	3,35	90,28
Minneapolis, USA (MSP)	3,24	87,32
Chicago, USA (ORD)	3,04	81,93
Madrid, ESP (MAD)	3,03	81,66
Detroit, USA (DET)	2,97	80,04
Dallas, USA (DFW)	2,97	80,04
Toronto, CSN (YBZ)	2,95	79,50
Mexico, MEX (NLD)	2,90	78,16
Harare, ZWE (HRE)	2,89	77,89
Washington, USA (WSG)	2,70	72,77
Houston, USA (IAH)	2,70	72,77
New York, USA (EWR)	2,63	70,88
Philadelphia, USA (PHL)	2,62	70,61
Atlanta, USA (ATL)	2,57	69,26
Joahnnesburg, ZAF (JNB)	2,54	68,45
Miami, USA (MIA)	2,24	60,37
Santiago, CHL (SCL)	0,58	15,63
Buenos Aires, ARG (EZE)	0,37	9,97
Florianópolis, BRA (FLN)	0,09	2,43
São Paulo, BRA (SDU)	0,07	1,89

When delegates of the Rio 6 Conference convene in Rio de Janeiro 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 Rio de Janeiro, calculated using the Atmosfair Emissions Calculator [3] and the equivalent carbon-trading market value at current prices [4]. In fact, some 95% of the greenhouse gas emissions related to the Rio 6 Conference will be due to air travel [5].

For our study-case Brazil, we also present figures comparing avoided emissions with the installation and operation of PV in airports to cover 100% of their electricity needs with the equivalent of burning fossil fuels in conventional generation units. Table 2 shows, specifically for coal, oil, and natural gas burning units, and also for the mix of thermal generation units in Brazil, the total annual amounts of CO_2 emissions that can be avoided with the integration of PV.

Table 2: Annual CO_2 emissions avoided by the operation of PV plants to supply electricity for all Brazilian airports instead of fossil fuel burning thermal generation units.

Fuel	CO_2/year (tons)
Coal	383,879
Oil	316,727
Natural Gas	176,094
Mix of thermal in Brazil	236,611

Who pays the bill

But 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 2005, over 3.9 billion passengers flew from the 1530 Airports Council International (ACI) - registered airports worldwide [6]. The ACI operates in 175 countries, and expects a 5% annual growth rate on these figures. Table 3 shows the 30 busiest airports worldwide, and the annual growth in passenger numbers from 2003.

Virtually "half of the world" travels by air every year, including most of our planet 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, as per the Rio '92 Environment and Development Declaration – Principle No. 16 [UNCED 1992], 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 solarize 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 all over the globe, stimulating 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. This will in turn benefit the estimated two billion people which still do not have access to electricity worldwide.

Table 3: Top 30 airports in passenger numbers worldwide.

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
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]

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/compensation. Extending this proposed US$ 2 per passenger/trip levy to all the ACI-registered airports worldwide, would generate funds in excess of 7 billion US$ per year for installing PV in airports alone, which is, by the way, in the range of the current global PV market [8]!

Going back to our study case Brazil, which corresponds to only 2.3% of worldwide air traffic, and using a conservative estimate, at a total installed PV system cost of US$ 7/Wp, and using year 2005 total passenger numbers and airport energy consumption, a US$ 2 surcharge per passenger/flight would generate enough revenue to install the 275 MWp previously mentioned and make all Brazilian airports 100% solar in less than 10 years. 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 larger than 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 [9].

Conclusions

We have shown the considerable potential of integrating PV on airport buildings and grounds, using Brazilian airports as our study-case, and a polluter-pays approach to finance the installation of solar electric systems on airports worldwide. We propose this as a voluntary measure by the air travel industry to compensate and mitigate the impact of air travel and airport operation, applying a small surcharge to air tickets that can make all airports 100% solar over 10 years.

Acknowledgments

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