THE POTENTIAL OF PHOTOVOLTAICS ON AIRPORTS

R. Rüther[1,2] , P. Braun[2] & C. Zomer[2]
[1]LABSOLAR – Laboratório de Energia Solar
[2]LabEEE – Laboratório de Eficiência Energética em Edificações
Universidade Federal de Santa Catarina, Caixa Postal 476
Florianopolis – SC, 88040-900 Brazil
Tel.: +55 48 3331 5174 e-mail: ruther@mbox1.ufsc.br

ABSTRACT: Airports are a perfect showcase for photovoltaics (PV), and integrating PV to airport buildings and airport grounds is also an ideal application for this distributed generation technology. The most influential people on the globe are regular customers of airport facilities, and since PV still lacks volumes and world-wide visibility to become mainstream, building-integrated photovoltaics (BIPV) shows a considerable potential to contribute, as we show in this work. In this paper we make the case for the global uptake of PV on airport buildings and airport grounds, showing that airport facilities are typically large enough to accommodate enough PV to turn most airports in the world self-sufficient in electricity. Furthermore, we show that the growing airtravel industry is also responsible for a considerable amount of greenhouse gas (GHG) emissions, and that a single passenger flying to any destination is typically responsible for GHG amounts that are not negligible in terms of carbon trade market value. PV on airports, financed by air travelers as a compensation for aircraft emissions can both make PV become mainstream, and contribute to a cleaner energy mix.
Keywords: PV on airports, solar airports, building-integrated photovoltaics.

1 INTRODUCTION

The incorporation of solar modules to airport buildings is one of the most ideal applications of building-integrated photovoltaics (BIPV). 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, 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.

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.

2 AIRPORT BUILDING POWER DEMANDS AND PV POTENTIAL

Figure 2 shows the passenger terminal and an aerial view of the Dresden (Germany) Airport, the gateway airport to many of the 21st European PV Solar Energy Conference 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 Dresden International Airport in Germany, is well suited for PV integration on both passenger terminal and grounds (www.falconcrest.com).

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 1.4 MWp, ground-mounted, grid-connected PV system since January 2004 [1], which was recently expanded to 4 MWp [2], and 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.

3 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 [3].

When delegates of this Conference convene in Dresden from 4 - 8 September 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 I shows the impressive amounts of per passenger/flight CO_2 emissions for flights from various airports to Dresden, 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 this Conference will be due to air travel [6].

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 II 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 when replacing fossil-fueled generation by PV.

4 LIABILITY: THE POLLUTER-PAYS PRINCIPLE

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 4.2 billion passengers flew from the 1650 Airports Council International (ACI) -registered airports worldwide [7]. The ACI operates in 175 countries, and expects a 5% annual growth rate on these figures. Table III shows the 30 busiest airports worldwide in 2005, and the annual growth in passenger numbers from 2004.

More than "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 [8], levying passengers through a surcharge on airport departure taxes or on air tickets can straightforwardly finance BIPV on 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 in a relatively short period of time. The potential is huge and could definitely and definitively contribute to 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 volume production. This will in turn benefit the estimated two billion people often referred to, who do not have access to electricity worldwide [9].

Table I: CO_2 emissions and equivalent carbon-trading market price of single-passenger airtravel do Dresden – Germany.

From - City (Airport)	tCO_2	€
Sydney, AUS (SYD)	7.81	124.57
Stockolm, PNG (SMP)	7.15	114.04
Santiago, CHL (SCL)	4.54	72.41
Buenos Aires, ARG (EZE)	4.30	68.59
Florianópolis, BRA (FLN)	3.87	61.73
São Paulo, BRA (GRU)	3.69	58.86
Rio de Janeiro, BRA (SDU)	3.60	57.42
Singapore, SGP (SIN)	3.59	57.26
Los Angels, USA (LAX)	3.43	54.71
San Francisco, USA (SFO)	3.35	53.43
Phonix, USA (PHX)	3.34	53.27
México, MEX (NLD)	3.30	52.64
Tokyo, JPN (NRT)	3.27	52.16
Hong Kong, CHN (HKG)	3.18	50.72
Joahnnesburg, ZAF (JNB)	3.15	50.24
Bangkok, THA (BKK)	3.11	49.60
Shangai, CHN (SHA)	3.05	48.65
Seattle, USA (SEA)	2.99	47.69
Miami, USA (MIA)	2.91	46.41
Harare, ZWE (HRE)	2.69	42.91
Atlanta, USA (ATL)	2.63	41.95
Beijing, CHN (PEK)	2.54	40.51
Washington, USA (WSG)	2.36	37.64
Philadelphia, USA (PHL)	2.26	36.05
Toronto, CAN (YBZ)	2.25	35.89
New York, USA (EWR)	2.22	35.41
New Dehli, IND (DEL)	1.96	31.26
Tel Aviv, ISR (TLV)	0.62	9.89
Cairo, EGY (CAI)	0.62	9.89
Madrid, ESP (MAD)	0.40	6.38
Athens, GRC (ATH)	0.38	6.06
Rome, ITA (FCO)	0.24	3.83
London, GBR (LHR)	0.24	3.83
Oslo, NOR (TRF)	0.22	3.51
Paris, FRA (ORY)	0.21	3.35
Brussels, BEL (BRU)	0.16	2.55
Amsterdam, DEU (AMS)	0.15	2.39
Budapest, HUN (BUD)	0.14	2.23
Zurich, DEU (ZHR)	0.12	1.91
Copenhagen, DNK (CPH)	0.09	1.44
Vienna, AUT (VIE)	0.07	1.12
Frankfurt, DEU (FRA)	0.07	1.12
Prague, CZE (PRG)	0.04	0.64
Berlin, DEU (TXL)	0.04	0.64

Source: Atmosfair Emissions Calculator [4[and Point Carbon (Aug 21, 2006)[5]

Table II: 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

5 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 quite often less privileged sectors of a given society are obliged to contribute to compensate damages not necessarily caused by them, or which will not necessarily revert in a direct benefit to them. In the present case there is no such conflict, as there is direct relation between emissions liability and contribution to emissions mitigation/compensation.

As a straightforward exercise, imposing a 2 EUROS per passenger/trip levy to all the ACI-registered airports worldwide, would generate funds in excess of 8 billion EUROS per year for installing PV in airports alone, which is, by the way, in the range of the current global PV market [10]! The current silicon feedstock shortage, and the prospect of instant doubling of PV module demand suggested by this exercise indicate that a more careful approach would be advisable, but putting such a concept in motion on a worldwide level would also take some time, perhaps enough for market confidence and market forces to adjust, and investments in feedstock supply and new thin-film technologies to materialize, so that a more orderly development might be envisaged.

Going back to our case study Brazil, which corresponds to only 2.3% of worldwide air traffic, and using a conservative estimate, at a total installed PV system cost of 7 EUROS/Wp, and using year 2005 total passenger numbers (96 millions) and airport energy consumption (420 GWh), a 2 EUROS 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 27.5 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” [11].

6 CONCLUSIONS

We have shown the considerable potential of integrating PV on airport buildings and airport grounds, using Brazilian airports as our case study, 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 partially compensate and mitigate the environmental impact of air travel and airport operation, applying a small surcharge to air tickets that can make all airports 100% solar over 10 years.

Table III: Top 30 airports in passenger numbers worldwide.

Rank	City (Airport)	Total passenger 2005	% Change From 2004
1	Atlanta, GA (ATL)	85,907,423	2.8%
2	Chicago, IL (ORD)	76,510,003	1.5%
3	London, GB (LHR)	67,915,389	0.8%
4	Tokyo, JP (HND)	63,282,219	1.5%
5	Los Angeles, CA (LAX)	61,485,269	1.3%
6	Dallas, TX (DFW)	59,064,360	-0.6%
7	Paris, FR (CDG)	53,756,200	5.7%
8	Frankfurt, DE (FRA)	52,219,412	2.2%
9	Las Vegas, NV (LAS)	44,280,190	6.9%
10	Amsterdam, NL (AMS)	44,163,098	3.8%
11	Denver, CO (DEN)	43,307,335	2.2%
12	Madrid, ES (MAD)	41,939,904	8.9%
13	Phoenix, AZ (PHX)	41,204,071	4.3%
14	Beijing, CN (PEK)	40,989,651	17.5%
15	New York, NY (JFK)	40,584,001	8.6%
16	Hong Kong, CN (HKG)	40,584,001	10.5%
17	Houston, TX (IAH)	39,713,920	8.8%
18	Bangkok, TH (BKK)	38,985,043	2.7%
19	Minneapolis, MN (MSP)	37,563,664	2.2%
20	Detroit, MI (DTW)	36,374,906	3.3%
21	Orlando, FL (MCO)	33,907,396	9.0%
22	San Francisco, CA (SFO)	33,580,662	0.2%
23	Newark, NJ (EWR)	33,033,569	3.7%
24	London, GB (LGW)	32,784,177	4.2%
25	Singapore, SG (SIN)	32,430,856	6.8%
26	Tokyo, JP (NRT)	31,525,275	1.3%
27	Philadelphia, PA (PHL)	31,502,855	10.5%
28	Miami, FL (MIA)	31,008,453	2.8%
29	Toronto, ON, CA (YYZ)	29,914,925	4.4%
30	Seattle/Tacoma, WA (SEA)	29,289,009	2.0%

Source: Airports Council International (ACI) [7]

7 ACKNOWLEDGMENTS

The authors would like to acknowledge with thanks the Brazilian Airports Authority INFRAERO for access to their extensive data on all airports in Brazil.

8 REFERENCES

[1] www.city-solar-ag.de/eng/projects.htm.

[2] S. Brust, *Facts on Saarbrücken Airport*, Private Communication with Mr. Stephan Brust – www.city-solar-ag.de, 16.01.2006.

[3] Editorial, *Clean, green conferencing*, Nature Vol. 432, 2004, 257.

[4] Atmosfair – *The atmosfair emissions calculator*, www.atmosfair.de.

[5] www.pointcarbon.com, On Aug 21st, 2006, the CO_2 trading market price was 15.95 Euro/ton.

[6] UNFCCC - United Nations Framework Convention on Climate Change, *Making the UNFCCC carbon neutral*, presented at the UNFCCC Technology sub-programme meeting – Buenos Aires, Argentina, December 2004.

[7] Airports Council International – ACI, *Annual Report 2004,* www.aci.aero.

[8] UNCED. United Nations Conference on Environment and Development - Rio92, Rio de Janeiro, Brazil, 1992.
[9] B. Mcnelis, *Photovoltaics = Development*, Keynote speech at the 17th European Photovoltaic Solar Energy Conference, Munich – Germany, 2001.
[10] J. Waldau, *PV Status*, Refocus May/June, 2005, 20.
[11] S. Krauter and R.Rüther, Considerations for the calculation of greehouse gas reduction by photovoltaic solar energy, Renewable Energy Vol. 29, 2004, 345.