ADDED VALUES OF PV SYSTEMS FROM THE SOCIETYS AND UTILITIES VIEWPOINTS

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ABSTRACT

International Energy Agency's research programme IEA-PVPS-Task 10 and the European research project PV-UP-SCALE emphasize "PV in urban areas". One activity of some collective works of these projects is dedicated to Value Analysis, whose major purpose is to identify, quantify and evaluate the values and benefits of building integrated grid connected PV systems. The identification of values will provide at least some sort of justification with regard the PV supporting strategies to remove financial barriers, which are heavily discussed elsewhere, and present the benefits to diverse stakeholders which are necessary for a wider market penetration of PV technology. The analysis of each value includes the derivation of a general methodological approach which is suitable for all countries/regions analysed, whilst the quantifiable examples aim to demonstrate country specific differences and perceptions.

Keywords: Values, benefits, grid connected PV systems.

1. INTRODUCTION

Although PV currently appears an expensive option for producing electricity compared to other energy sources many countries support this novel technology because of its promising future potential and the additional benefits besides generating electricity associated with PV. Countries like Japan and Germany detected the importance of diversity in their electricity market in order to be not dependent on imported fossil energy and produce clean energy form PV.

These benefits need to be, firstly, identified and, secondly, quantified -especially for the demand side- in order to affect decision making in urban planning. This paper takes the topic into account from the policy makers and utilities point of view and aims to clarify; on the one hand why policy makers set strong market incentives and why electricity utilities should invest in PV Systems or PV electricity. In this respect the perceived values can be categorised under the following groups.

- Avoiding fossil fuels
- Environmental Benefits and
- Electric utilities benefits

From a geographical viewpoint this study focus on: Austria (AT), Canada (CAN), Denmark (DK), France (FR), Germany (DE), Japan (JP), The Netherlands (NL), Spain (ES), Sweden (SE), United Kingdom (GBR), California / United States of America (USA)

2. AVOIDING FOSSIL FUELS

PV, as a renewable energy technology, may substitute for thermal power generation based on fossil fuels and hence avoid risks of disruption in fossil fuel supply and associated price instability. In a competitive and liberalised power market it is difficult to determine which kind of energy is actually displaced by adding another power plant to the system. However, in the following we present an approach suitable for a quantification based on few key assumptions.

2.1 Determining the replaced fuel

The fossil fuels identified as likely to be avoided differ from country to country. Accordingly, for this study, country-specific data on the yearly electricity generation portfolio as well as information on the technology-specific contribution in meeting base-intermediate and peak-demand has been collected. Table I comprises the assumptions on replaced fuels for reported countries.

2.2 Quantifying the replaced fuel

The primary energy equivalent of PV electricity has been calculated according to the partial substitution method which can be summarised by the equation below (1).

Replaced thermal fuel in terms of primary energy (kWh) = PV generation (1 kWh) / Average generation efficiency (%)

Table I summaries the assumptions on replaced thermal fuel and results on calculated avoidance of thermal fuel by 1 kWh PV generation.

Table I. Summary of Calculated Avoided Thermal Fuel for Various Countries

Country	Replaced Fuel (Assumed)	Generation Efficiency Factor (Thermal power plant)	Avoidance of thermal fuel by 1 kWh PV generation [kWh]
AT	Hard Coal	0.39	2.56
CAN	Coal	0.40	2.50
CH	Natural Gas	0.39	2.56
DE	Hard Coal & Lignite	0.43	2.33
DK	Hard Coal	0.41	2.44
ES	Hard Coal	0.36	2.78
FR	Hard Coal	0.40	2.50
GBR	Hard Coal	0.42	2.41
JP	Oil	0.38	2.63
NL	Natural Gas	0.39	2.56
SE	Natural Gas	0.39	2.56
USA - California	Natural Gas	0.39	2.56

3. ENVIRONMENTAL BENEFITS

3.1. Avoided greenhouse gas emissions (CO_2-eq) and air pollutants (NO_X and SO_2)

By replacing conventional fossil-based power supply, PV contributes also to the avoidance of corresponding greenhouse gas emissions (CO2-eq) and air pollutants such as sulphur (SO2) and nitrogen oxides (NOX). For the quantification of reduced emissions, a net balance was derived by taking into account country-specific (life-cycle) emissions factors by fossil fuel (2), (3), (4) as well as (life-cycle) emissions factors of PV relating to the manufacture of PV cells (5),(6). As a result, for each generated kWh of PV electricity, reduced emissions factors could be calculated on a country level. Table II depicts the derived results on net emissions factors by country.

Table II. Summary of Net Reduced Emissions Factors Based On Fuel and Used Cells (7) For Various Countries

Country	Net reduced emissions factor based on replaced fuel and used solar cells [g/kWh]		
	CO_2-eq	NO_X	SO_2
AT	896	0.75	0.67
CAN	959	1.18	5.07
CH	377	1.27	-0.14
DE	1042	0.55	0.38
DK	890	0.74	0.65
ES	921	3.74	6.89
FR	899	0.76	0.68
GBR	1048	3.37	0.9
JP	694	0.21	0.07
NL	350	1.39	-0.16
SE	370	1.26	-0.16
USA (California)	462	0.5	0.22

The results indicate that the highest GHG emission reduction factors occur for United Kingdom (GBR) where 1 kWh PV electricity contributes to the avoidance of 1048 g CO2-eq from hard coal-fired power plants, whilst in the case of Spain the highest reduction with respect to the air pollutant NOX is feasible (1kWh PV contribute to avoid 6.89 g NOX). The analysis shows that in European countries where PV possibly replaces natural gas higher SO2 emissions occur – due to comparatively high emissions that refer to the manufacturing of solar cells. In contrast, in California where again natural gas represents the marginal option, this negative effect of an enhanced PV deployment cannot be observed since the upstream air pollutant emissions in the life-cycle of natural gas power plants are comparatively high (4).

3.2. External Costs

The external cost of energy supply is another intensively discussed topic. Based on the outcomes of a recently conducted evaluation report (8) of several external cost studies indicators can be derived for the avoided external cost due to PV electricity. According to the final outcomes of this report the median valuation for loss expenses of the climate change is 70 €/t CO2. The loss expenses for air pollutants are; 3280 €/t NOX and 3320 €/t SO2. The total potential of reducing external costs by considering these values derives that in the case of Spain, where coal represents the avoided marginal conventional supply option, a high value of 9.95 €cent/kWh appears, whilst in the Netherlands with its gas-based peak supply, only 2.86 €cent/kWh occurs. Therefore, we can assume that where PV replaces coal the external cost reduction is higher than when natural gas is replaced, even if solar conditions are moderate.

4 UTILITIES BENEFITS

Values for utilities depend largely on country-specific supply and climatic conditions. In this paper we will discuss two values from utilities point of view.

- The relevance of PV to meet peak demand
- The relevance of PV for reducing the environmental cost burden – like CO_2 certificate prices applied within the European Union's Emission trading scheme.

4.1. The relevance of PV to meet peak demand

The relevance of PV for meeting peak demand depends on the daily and seasonal load characteristics, e.g. the time of daily peaks and the correlation with solar generation. In this context, the following question appeared: To what extent can PV contribute to peak supply? Based on country-specific load profiles we classify European countries as typical “winter peak” countries, but the recent hot and dry summer conditions have clearly shown that there is a need to reduce peak electricity demand or supply shortage, even during summer. In this season many thermal power plants undergo maintenance or have to reduce their generation due to a lack of cooling water. As studies on “capacity credit of PV”[1] indicate, PV as an option to reduce supply shortage in peak load periods has mainly been considered a topic for “summer peaking” locations like Japan and California - where the main literature is coming from. However, recent summers in Europe have shown that this value may get more important for European countries as electricity from Photovoltaic systems is generally produced during times of peak demand when electricity is most expensive in summer months.

Figure 1 shows the correlation between PV output and spot prices for Austria and Spain for the year 2003. The correlations were derived from data on hourly spot prices for the corresponding electricity markets and data on PV output for a reference system. In more detail, the Austrian PV reference system is located in Vienna whilst the reference system for Spain refers to the city Tarragona. Data on spot market prices have been taken from EXAA (9) for Austria and for Spain from OMEL (10).

The hourly average correlation between PV output and spot prices for summer and winter months confirms that PV generation matches best to peak prices during summer in central European countries. In Spain, representing southern Europe, the peak prices during summer months continue from midday on until night hours (see Figure 1).

Figure 2 shows the correlation of PV output and spot prices for France and Sweden for the year 2004. The reference PV systems used are located in Lyon (France) and Stockholm (Sweden) and spot prices were derived from Powernext (11) and Nord Pool (12).

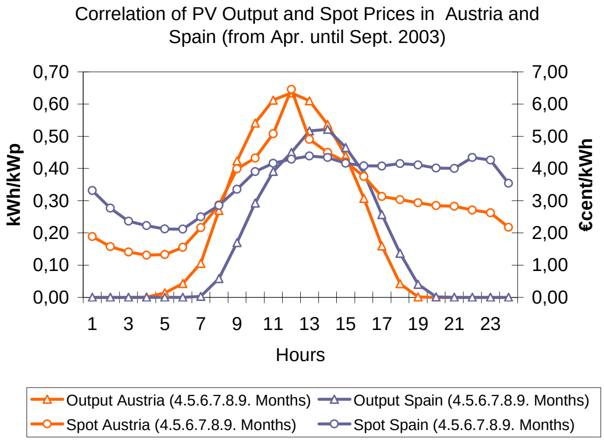

Fig. 1 Correlation of PV output and spot prices in Austria and Spain[2] in 2003 during warm season (April to Sept.)

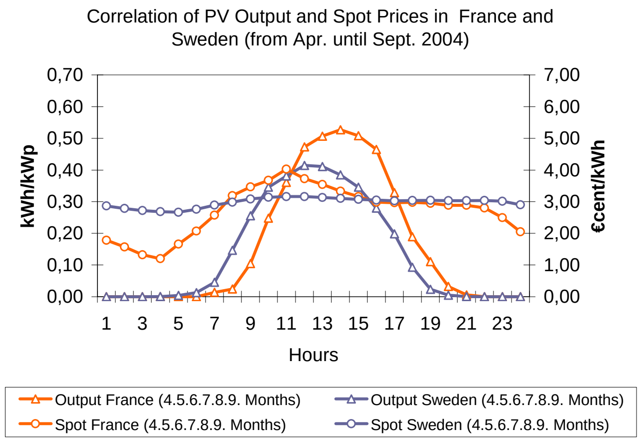

Fig 2 Correlation of PV output and spot prices in France and Sweden in 2004 during warm season (April to Sept.)

Due to the dominance of hydropower the price levels in the Nordic market are low. France, being the largest nuclear generator in Europe and a major electricity exporter, also has low price levels in comparison to central and southern European countries. For Sweden it can be suggested that there is no correlation between PV output and spot prices. In the case of France it is possible to say that the peak price in the summer occurs at about 12 o’clock midday which

[1] What capacity reduction can be made in the conventional power plant mix by the addition of PV capacity or, in other words, to what extent can PV provide power when a utility needs it.

[2] Pease note that these reference systems represent a country just in terms of correlations, i.e. by delivering representative generation profiles. The PV output of the reference system in Spain is very low compared to Austria. This can be explained by the hot summer of 2003 in Austria and a low performance ratio for the Spanish reference system. The average yearly solar irradiation for Tarragona is actually high – a figure of 1498 kWh/m²/a occurs (13)

means demand is high and PV output also typically peaks.

4.2. The relevance of PV for reducing the environmental cost burden – Cost of CO2 certificate

Within the European Union an emission trading scheme has been implemented since the end of 2004. The utilities had to pay 18 Euro on average (14) (from 2005 to October 2006) for each tonne of emitted CO2. As market prices of allocated allowances represent opportunity costs, the introduction of an emission trading scheme affects marginal electricity generation costs. Taking into account the potential CO2 emissions reductions factors for PV and given certificate price levels we can determine monetary savings for the utilities for each alternatively generated kWh PV electricity. This is done for all reported European countries as Table 3 indicates. Derived from this table in the Netherlands a utility can reduce its cost burden by about 0.62 €cent for each kWh generated PV electricity, whilst the highest value in size of 1.86 €cent/kWh occurs for United Kingdom where avoidance of hard coal was assumed.

Table III. Contribution of PV Electricity in CO_2 Certificate Price Saving For Utility

Reducing Cost of CO_2 Certificate by PV generation [€cent/kWh]							
AT	DE	DK	ES	FR	GBR	NL	SE
1.59	1.85	1.58	1.64	1.60	1.86	0.62	0.66

5. CONCLUSIONS

The value analysis gives justification for the strong incentives which are needed to achieve an enhanced market deployment as well as the dissemination of urban planning of PV. PV systems contribute to supply security through avoiding the use of (imported) fossil fuels and reduce fuel price risks respectively. Which fossil fuel can be avoided by using PV electricity differs from country to country. Exemplarily results for the UK, representing a northern country with low solar yields, indicate that environmental benefits are similarly high like in Spain characterised by paper solar conditions. Furthermore PV systems reduce greenhouse gas emissions and air pollutants and accordingly avoid external costs which alternatively have to be borne by the whole society.

From the utilities point of view PV can contribute to peak shaving which means PV electricity is available especially in the summer months when demand is rising and accordingly the electricity prices are high. While the importance of greenhouse gas reduction is getting a key energy policy issue -at least for most industrialised countries- this policy represents a monetary burden for utilities which can be reduced by generating alternatively PV electricity.

5. ACKNOWLEDGMENTS

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