

# Analysis of incentive systems for photovoltaic power plants in six countries of the European Union

M. Pasetti<sup>1</sup>, P. Iora<sup>1</sup>, P. Chiesa<sup>2</sup>, C. Invernizzi<sup>1</sup> and A. Salogni<sup>1</sup>

<sup>1</sup> Department of Mechanical and Industrial Engineering  
Università degli Studi di Brescia  
Via Branze, 38 – 25123 Brescia (Italy)

Phone: +39 030 3715581, e-mail: [marco.pasetti@ing.unibs.it](mailto:marco.pasetti@ing.unibs.it), [paolo.iora@ing.unibs.it](mailto:paolo.iora@ing.unibs.it),  
[costante.ivernizzi@ing.unibs.it](mailto:costante.ivernizzi@ing.unibs.it), [andrea.salogni@ing.unibs.it](mailto:andrea.salogni@ing.unibs.it)

<sup>2</sup> Department of Energy  
Politecnico di Milano  
Campus Bovisa – Via Lambruschini, 4 – 20156 Milano (Italy)  
Phone: +39 02 23993916, e-mail: [paolo.chiesa@polimi.it](mailto:paolo.chiesa@polimi.it)

## Abstract

This paper compares the different incentive systems in support to the photovoltaic power generation in force in six countries of the European Union: Austria, France, Germany, Italy, Portugal and Spain. For the proper solar radiation of each location and two different plant sizes (one, from 1 to 3 kW<sub>p</sub>, typical of domestic installations, the other larger than 100 kW<sub>p</sub>), an economic analysis is carried out aiming to assess the actual cost of electricity and the return on the investment allowed by the current incentives.

## Key words

Photovoltaic subsidies, economic analysis.

## 1. Introduction

Feed-in tariff subsidies schemes for photovoltaic power plants have been adopted in Germany since 2001. In the following years other EU countries have promoted analogous incentive strategies. Although all the schemes proposed are based on a feed-in tariff model – i.e. by rewarding the energy produced, instead of refunding part of the capital cost of the PV plant – a comparison among the different incentive systems is not straightforward, owing both to the specific incentive conditions adopted and to the insolation characteristics of each country.

The aim of this work is to evaluate the profitability of an investment in solar photovoltaic plants in six country of the European Union<sup>1</sup>: Austria, France, Germany, Italy, Portugal and Spain. To this purpose PV incentive patterns operating in each country are considered in correspondence with the specific insolation characteristics of the site. An economic analysis is then

carried out for two different plant size: a small photovoltaic plant (from 1 to 3 kW<sub>p</sub>), representative of a domestic application, and a fairly large plant (larger than 100 kW<sub>p</sub>). In the following, the acronyms SPV (small photovoltaic) and LPV (large photovoltaic) will be used to refer to these two power plants. This distinction is necessary as the two cases analyzed are generally characterized by different specific capital investments, subsidies conditions and taxation mechanisms. As a matter of fact, economic conditions typical of an average family can be applied to SPV, while the installation and operation of LPV is attributed either to an electric company or to a financial society.

To compare the incentive schemes, is therefore necessary to: (i) calculate mean yearly insolation data for every considered site; (ii) define the regulatory scheme in force in each country; (iii) carry out an economic analysis along the expected life of PV plants. These issues will be considered in the following paragraphs.

## 2. Calculation of solar radiation and electricity production

The calculation of solar radiation and electricity production in each country is carried out by means of the Joint Research Centre's PVGIS software [1]. PVGIS (Photovoltaic Geographical Information System) is a web-based application that provides a map-based inventory of solar energy resources and an assessment of the electricity generation from photovoltaic systems in Europe. This application is used to calculate the solar radiation at a given location (for both conditions of fixed and optimal orientation), and to evaluate the electric production of PV plants depending on the selected PV technology (Crystalline Silicon, CIS and CdTe), local temperatures, orientation and inclination of PV modules and the estimated system losses (due to several factors, such as inverter efficiency, cable losses, mismatching, cleanness of the modules surface, etc.) [2].

<sup>1</sup> This paper is a review of a previous work which provides a simplified analysis of the incentives systems in force in four countries of the European Union (Iora et al., 2006).

For this analysis a distinctive city has been considered as representative of each country (Figure 1) and the following conditions and parameters have been considered for the calculus of solar radiation and electricity production:

- condition of optimal orientation<sup>2</sup>;
- crystalline Silicon technology;
- estimated system losses: 14%.

Data used to carry out the analysis are reported in Table I. It is worth to note that they are consistent with those given by other authors [3], [4].

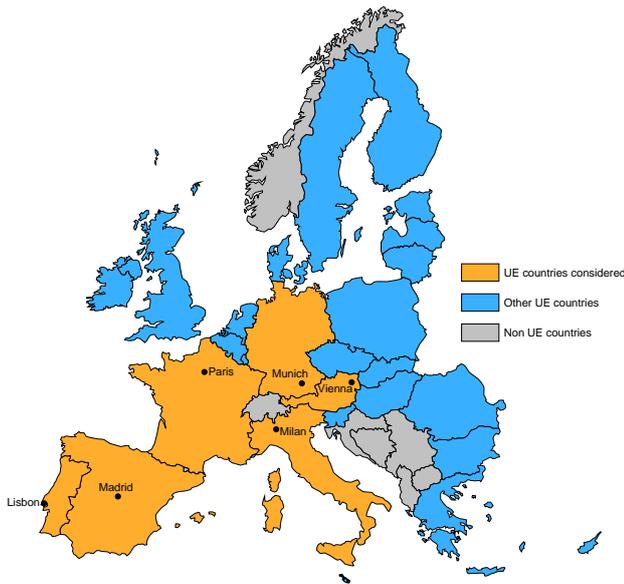


Figure 1. Geographic position of the six cities considered in the analysis.

Country	City	Solar radiation [kWh/m <sup>2</sup> ·year]	Energy production [kWh/kW <sub>p</sub> ·year]
Austria	Vienna	1300	996
France	Paris	1260	956
Germany	Munich	1300	1000
Italy	Milan	1470	1120
Portugal	Lisbon	1860	1390
Spain	Madrid	1870	1400

Table I. Average yearly global irradiation and average yearly electricity production for the considered sites [1].

### 3. Incentive conditions

This sections deals with the incentive systems in support to the photovoltaic power generation in force in the six countries considered in this analysis.

<sup>2</sup> depending on the given location. The azimuth and tilt angles are provided by PVGIS [1],[2].

#### A. Austria

In Austria, according to the 2009 Green Electricity Regulation, a feed-in tariff subsidies scheme is granted for a period of 13 years. The incentives in force in 2009, depending on the plant size, are as follows [5], [6]:

- system size < 5 kW<sub>p</sub>: 0.4598 €/kWh
- system size 5 ÷ 10 kW<sub>p</sub>: 0.3998 €/kWh
- system size > 10 kW<sub>p</sub>: 0.2998 €/kWh

Grants for renewable project investments are also available, varying from region to region, mainly delivered as investment subsidies and low cost loans; however, since this support cannot be cumulated with feed-in tariffs, it is mainly requested only by stand alone installations [3].

#### B. France

Set up in 2002, the French subsidies scheme for photovoltaic plants has been redefined by the Financial Law approved on July 26, 2006. Based on this new incentive system, the feed-in tariffs in force in 2009, granted for a period of 20 years, are as follows [5], [6]:

- a 0.32 €/kWh basic tariff (up to 0.42 €/kWh in Corsica and Overseas Departments), regardless the dimension and the owner of the plant;
- a 0.25 €/kWh bonus (0.15 €/kWh in Corsica and Overseas Departments) for building integrated installation;
- a 0.45 €/kWh tariff for rooftop installation on commercial buildings;
- all the tariffs are annually revised according to the corrected inflation rate.

Besides this, 50% of the investment costs are tax deductible and a lower VAT (5.5%) on system costs (excluding labor) is applied. For enterprises, an accelerated depreciation is also available. In addition, the electricity produced is sold to the grid at 0.13811 €/kWh (price of 2006) [3].

#### C. Germany

The new feed-in tariff subsidies scheme (granted for 20 years) passed the German Parliament on June 6, 2008 and is valid from January 1, 2009. Tariffs for new installations are as follows [5], [6]:

- system size < 30 kW<sub>p</sub>: 0.4301 €/kWh
- system size 30 ÷ 100 kW<sub>p</sub>: 0.4091 €/kWh
- system size 100 kW<sub>p</sub> ÷ 1 MW<sub>p</sub>: 0.3958 €/kWh
- system size > 1 MW<sub>p</sub>: 0.33 €/kWh

#### D. Italy

The Italian photovoltaic subsidies scheme, approved on February 23, 2007, grants feed-in tariffs for a period of 20 years. The incentives in force in 2009, depending on the type and size of the installation, are as follows (for

not integrated, partly integrated and building integrated plants respectively) [5], [6]:

- system size  $1 \div 3 \text{ kW}_p$ : 0.392, 0.431, 0.480 €/kWh
- system size  $3 \div 20 \text{ kW}_p$ : 0.372, 0.412, 0.451 €/kWh
- system  $> 20 \text{ kW}_p$ : 0.353, 0.392, 0.431 €/kWh

Besides this, the following noncumulative feed-in tariffs additions are also applied:

- a 5% bonus if the 70% of the electricity produced by the PV plant is directly used by the owner (only in case of not integrated systems larger than  $5 \text{ kW}_p$ );
- a 5% bonus for all the systems on schools and public health buildings, as well as for all the public buildings of communities with less than 5,000 inhabitants;
- a 5% bonus for integrated systems realized as replacement of asbestos roofs on buildings and farms.

The net metering option is available for plants up to  $200 \text{ kW}_p$ .

#### E. Portugal

The Independent Power Producer (IPP) Law, under which a feed-in tariff scheme for PV up to  $150 \text{ MW}_p$  was operated, is currently suspended. In November 2007 the micro-generation scheme was launched and has been fully operational since March 2008. The incentive system consists into two different regimes [6]:

- General Regime: this is available for any type of micro-generation source with a maximum capacity of  $5.75 \text{ kW}_p$ . The feed-in tariff is the same as the regulated tariff (true net meeting) set annually by the regulator;
- Special Regime: only for renewable energy sources with a capacity up to  $3.68 \text{ kW}_p$ . The initial feed-in

tariff was set at  $0.65 \text{ €/kWh}$  and then reduced by 5% each  $10 \text{ MW}_p$  of the installed capacity (not only PV). In April 2009 the tariff was reduced to  $0.6175 \text{ €/kWh}$ .

All installations must have at least  $2 \text{ m}^2$  of solar thermal panels installed. Reduction of VAT rate (from 21% to 12%) on renewable equipment, custom duties exemption and income tax reductions (up to €800 for solar equipment) are also available. The tariff is granted for a period of 15 years.

#### F. Spain

Set up in 2004, the Spanish subsidies scheme for photovoltaic plants has been redefined on September 2008. Based on this new incentive system, the feed-in tariffs in force in 2009, granted for a period of 25 years, are as follows [5], [6]:

For building integrated and rooftop installations:

- system size  $< 20 \text{ kW}_p$ :  $0.34 \text{ €/kWh}$
- system size  $20 \text{ kW}_p \div 2 \text{ MW}_p$ :  $0.32 \text{ €/kWh}$

For ground mounted installations:

- system size  $< 10 \text{ MW}_p$ :  $0.32 \text{ €/kWh}$

Because of the many possible combinations available for each country subsidies scheme, in this analysis only the basic tariffs will be considered, according to the system size. This means that no bonus or special tariffs will be applied (such as for rooftop, build integrated installations and particular sites). However, all the incentive conditions other than the feed-in tariffs (such as capital incentive, electricity sale conditions and tax depreciations), will be considered.

The incentive conditions assumed for the following economic analysis are summarized in Table II.

Country	Plant size	Subsidy [€/kWh]	Subsidy period [years]	Electricity sale conditions [€/kWh]	Capital incentive
Austria	SPV	0.4598	13	Sold at $0 \text{ €/kWh}$	Not present
	LPV	0.2998	13	Sold at $0 \text{ €/kWh}$	Not present
France	SPV	0.32	20	Sold at $0.13811 \text{ €/kWh}$	50 % of material costs
	LPV	0.32	20	Sold at $0.13811 \text{ €/kWh}$	Not present
Germany	SPV	0.4301	20	Sold at $0 \text{ €/kWh}$	Not present
	LPV	0.3958	20	Sold at $0 \text{ €/kWh}$	Not present
Italy	SPV	0.392	20	Net metering, $0.15 \text{ €/kWh}^*$	Not present
	LPV	0.353	20	Sold at $0.0957 \text{ €/kWh}$	Not present
Portugal	SPV	0.6175	15	Sold at $0 \text{ €/kWh}$	Not present
	LPV	Not present	Not present	Not present	Not present
Spain	SPV	0.32	25	Sold at $0 \text{ €/kWh}$	Not present
	LPV	0.32	25	Sold at $0 \text{ €/kWh}$	Not present

\* Average cost for electricity for an household with an electricity demand of about  $4000 \text{ kWh/year}$

Table II. Incentive conditions for small domestic PV plants (SPV) and large PV plants (LPV).

## 4. Economic analysis

This chapter aims to assess the cost of the solar electricity production (with and without subsidies) which, to a large extent, corresponds to the recovery of the initial investment calculated by applying an year-by-year, current-currency cash flow analysis, based on [7], with some modifications, as provided by [8].

The hypotheses adopted for such analysis are summarized in Table III, while a brief description of this methodology is provided in the following.

	SPV	LPV
Total investment cost [ $\text{€kW}_p$ ]	5500	4500
Inflation rate [%]	2	2
Return on equity [%]	15	15
Return on debt [%]	6	6
Debt share of the investment [%]	55	55
Plant expected economic life [years]	30	30
Debt return period [years]	20	20
Depreciation for tax purposes [%]	-	10
Return on debt ratio discounted from the income tax [%]	19	-
Return on debt ratio discounted from the taxable income [%]	-	100
Income tax rate [%]	30	40
Operation and maintenance cost [ $\text{€kW}_p \cdot \text{year}$ ]	18	18

Table III. Hypothesis assumed for the economic analysis of domestic (SPV) and large (LPV) plants.

### A. LPV plants

Given the short construction schedule typical of PV plants, regardless their size, we assume to neglect allowances for funds used during the construction, so that the total capital investment required to realize the plant coincides with the overnight plant cost, that has been assumed to  $4500 \text{ €kW}_p$ , including any additional expenses (i.e. prepaid royalties, costs for authorizations, start-up, inspection and inventory capital). The total investment consists of common equity and debt (so that are excluded other forms of financing such as preferred stocks, long term leasing and project financing), with a debt share set to 55% of the net investment. The investment is considered as made in a single payment occurring in December of year 0, assumed as reference, meaning that commercial operations start on January of year 1. The debt is refunded through a 6% fixed rate mortgage at constant installments over a period of 20 years, while the residual value of the plant at the end of its expected lifetime (assumed equal to 30 years) is set to zero. The nominal return on equity has been assumed

equal to 15%, a typical value used for power plants economic analysis. For tax purpose, a 40% income tax rate and a recovery period of 10 years, with straight line depreciation, have been considered. Finally, the operation and maintenance cost has been set to  $18 \text{ €kW}_p \cdot \text{year}$ , according to [9].

### B. SPV plants

Typical economic conditions of an average family are considered for the small photovoltaic plant analysis; with reference to the case of LPV, the following assumptions are made:

- overnight cost is increased to  $5500 \text{ €kW}_p$ , as the scale advantages proper of large plants are not applicable in case of SPV;
- income tax rate is reduced to 30%, a more representative value for an average family;
- depreciation for tax purposes is not allowed for domestic plants;
- 19% of the return on debt is discounted from income taxes<sup>3</sup>, (while the whole return on debt are entirely discounted from taxable income in case of LPV).

## 5. Results and discussion

The economic analysis carried out over the plant lifetime allows to determine some key economic indicators: (i) the unsubsidized cost of kWh, (ii) the subsidized cost of kWh, and (iii) the internal rate of return of the investment, IRR, which can be used to compare the different PV incentive policies. In particular:

- the unsubsidized (actual) cost of kWh (CUE) is the unit cost of the energy produced by the PV plant. It is calculated considering the overall costs and the energy produced through the entire plant lifetime, regardless the subsidies scheme. In other words, it indicates the price which should be applied to the electricity in order to refund the total investment (common equity and debt) at the end of the assumed operating life of the power plant.
- the subsidized cost of kWh (CSE) is evaluated with the same approach as before, except for considering the subsidies revenue within the annual cash-flow. It provides an indication about the effectiveness of the incentive scheme. Also note that, in general, the difference between CUE and CSE differs from the actual incentives because the analysis provides the average costs of the electricity (at constant money) over the whole plant lifetime, while incentives could vary in the years or have a shorter duration.
- IRR is the return rate which can be earned on the invested capital. Mathematically the IRR is defined as the discount rate that brings to a zero net present value in the cash-flows, calculated over the assumed economic lifetime of the investment. In this analysis

<sup>3</sup> This is, for instance, the condition presently in force in the Italian taxation system.

the debt book life is varied in order maximize the IRR, keeping fixed the debt share of the investment given in Table III. Finally, in the case of SPV, a 3% interest rate on the gained capital is considered instead of the return on equity; this value is more

representative of interest rates on low risk investment usually afforded by privates or small investors.

The results of the economic analysis are shown in Table IV and plotted in Figure 2 and Figure 3.

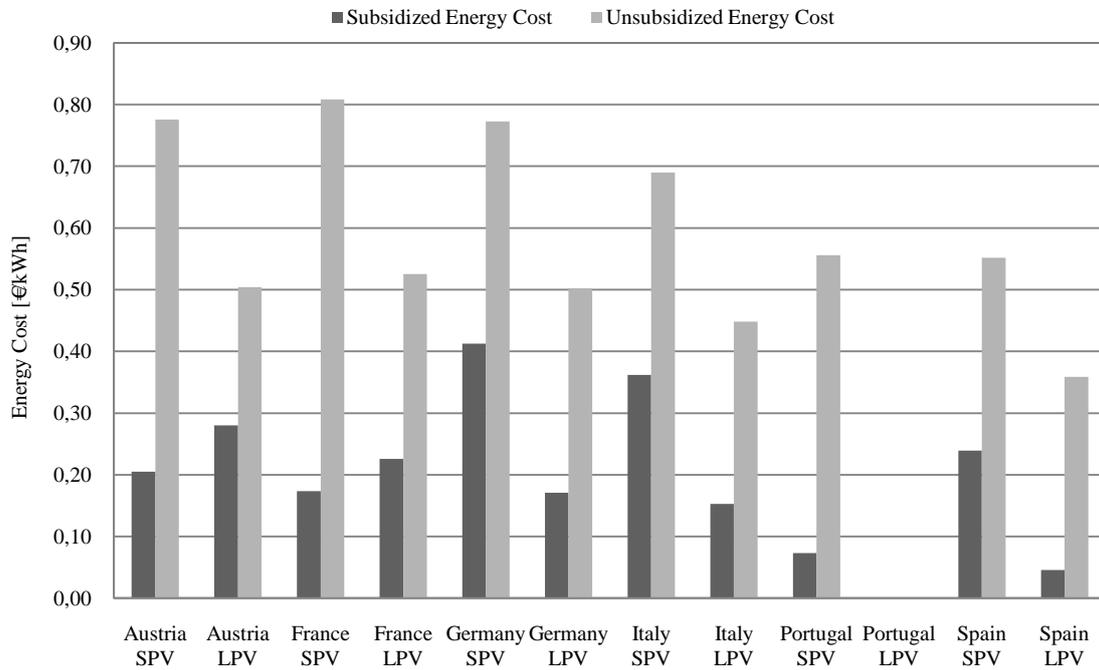


Figure 2. Subsidized and unsubsidized costs of the PV electricity in the six countries considered in the analysis.

Country	IRR [%]		Subsidized energy cost [€/kWh]		Unsubsidized energy cost [€/kWh]	
	SPV	LPV	SPV	LPV	SPV	LPV
Austria	3,0	0,8	0,21	0,28	0,78	0,50
France	13,1	11,3	0,17	0,23	0,81	0,53
Germany	0,8	6,5	0,41	0,17	0,77	0,50
Italy	9,3	12,0	0,36	0,15	0,69	0,45
Portugal	9,4	-	0,07	-	0,56	-
Spain	5,5	12,9	0,24	0,05	0,55	0,36

Table IV. Results of the economic analysis.

Figure 2 reports the cost of kWh for subsidized and unsubsidized electricity. The latter varies from a minimum of 0.36 €/kWh for Spain-LPV to a maximum of 0.81 €/kWh for France-SPV. As identical economic conditions have been assumed for all the countries, differences in the actual cost of kWh are only due to a different solar radiation. The actual cost of kWh is lower for LPV than for SPV plants, owing both to the lower specific overnight costs and to the more favorable taxation conditions (i.e. against a higher tax rate, we assumed that the LPV plant owner may have higher tax reductions from capital depreciation and discounts on the return on debt). It is worth to note that the resulting actual costs of the PV electricity are much higher than the

average market price of electric energy in Europe, currently about 0.12 €/kWh [10] (that is three times cheaper than the lowest unsubsidized PV energy cost).

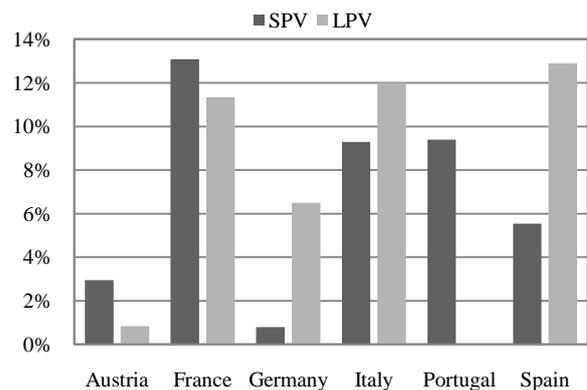


Figure 3. Internal Rate of Return (IRR) for PV investments in the six countries considered in the analysis.

Regarding to the subsidized cost of kWh; it can be noted that:

- from a comparison between LPV and SPV, it comes out that the lower costs are obtained for large applications, with the exception of France, where a capital subsidy is provided to SPV, and Austria, where small applications take advantages from the tax exemption. For instance, in the French case, a

contribution of 2338 € is considered, calculated as the 50% of the materials cost (assumed equal to 85% of the total costs).

- the highest subsidized cost of energy is reached by the Germany-SPV case, with 0.41 €/kWh. It is worth to note that this value is much higher than all the other cases, except for the Italy-SPV case, that is quite close, with a value of 0.36 €/kWh.
- the lowest subsidized cost of energy is reached by the Spain-LPV case, with 0.05 €/kWh, neared only by the Portugal-SPV case, with a value of 0.07 €/kWh.

Results in terms of IRR for each country are shown in Figure 3. The analysis reports as follows:

- France (both SPV and LPV) got the best results, with 13.1% for the SPV case and 11.3% for the LPV one, neared only by Spain-LPV and Italy-LPV, with 12.9% and 12.0% respectively.
- Austria (especially LPV) and Germany-SPV cases have obtained the worst results, with 0.8% both.
- Italy-SPV, Portugal-SPV, Spain-SPV and Germany-LPV reported results in the intermediate range.

## 6. Conclusions

In this work the incentive schemes for photovoltaic power plants adopted in six European Countries (Austria, France, Germany, Italy, Portugal and Spain) has been studied. An economic analysis has been carried out starting from the solar radiation data available for six representative cities of the countries considered. The analysis is applied to two different plant sizes (one, from 1 to 3 kW<sub>p</sub>, typical of domestic installations, the other larger than 100 kW<sub>p</sub>) and takes into account the different specific capital investments, subsidies conditions and taxation mechanisms. A comparison between the different incentive solutions is made by means of three key economic indicators: (i) the actual cost of kWh, (ii) the subsidized cost of kWh and (iii) the internal rate of return of the investments, IRR. Among the results obtained with this analysis it is worth to emphasize that:

- the lowest actual cost of PV electricity is observed for large plants installed in Spain (0.36 €/kWh), due to the fact that this country has the highest insolation rate; the same reason leads France to have the highest actual kWh cost (0.81 €/kWh for SPV).
- in general, large photovoltaic plants show lower actual electricity costs if compared to the small applications, due to the lower plant costs and to the more favorable taxation conditions. Nevertheless, the incentive conditions in force in France and Austria provide a significant support to small plants: in France through investment subsidies given to private owners only, and in Austria thanks to the tax exemption allowed to small size plants.
- assuming the same overnight plant cost for all the considered countries permits an homogeneous comparison, on the other hand, leads to an unexpected

result for Germany-SPV, where the investments are not recovered at the end of the plant lifetime. However, it should be taken into account that in Germany the existing PV market is far more developed than in the other countries, which leads to lower overnight cost and, thus, allows the investment repayment.

- results in terms of the internal rate of return (IRR) show that the investment in large PV plants is less attractive than that in traditional energy generation systems, where an IRR of 15% should normally be expected. As far as SPV plants are concerned, their profitability mostly depends on the incentive policy adopted by each country. For instance, France reported an IRR value for domestic applications of about 13%, making the investment more attractive than in Portugal (IRR less than 10%), which is though characterized by better solar radiation conditions.

## 7. References

- [1] JRC Institute for Energy, PVGIS, European Commission Joint Research Centre, 2009, <http://re.jrc.ec.europa.eu/pvgis/apps3/pvest.php>.
- [2] JRC Institute for Energy, PVGIS Release Notes, European Commission Joint Research Centre, 2009, [http://re.jrc.ec.europa.eu/pvgis/apps3/PVcalchelp\\_en.html](http://re.jrc.ec.europa.eu/pvgis/apps3/PVcalchelp_en.html)
- [3] Weiss, I., Orthen, S., Stierstorfer, J., Gisler, R., 2006. Assessment of 12 national policy frameworks for photovoltaic Country Analyses. Benchmarks. Conclusions. European Best Practice Report, [http://www.epia.org/documents/PV\\_Policy\\_Group\\_European\\_Best\\_Practice\\_Report.pdf](http://www.epia.org/documents/PV_Policy_Group_European_Best_Practice_Report.pdf).
- [4] Duffie, J.A., Beckman, W.A., 1991. Solar Engineering of Thermal Processes", 2nd ed., Wiley Interscience, New York.
- [5] JRC Institute for Energy, PV Status Report, European Commission Joint Research Centre, 2008, <http://re.jrc.ec.europa.eu/refsys/pdf/PV%20Report%202008.pdf>.
- [6] JRC Institute for Energy, PV Status Report, European Commission Joint Research Centre, 2009, <http://sunbird.jrc.it/refsys/pdf/PV-Report2009.pdf>
- [7] Campanari, S., Chiesa, P., Silva, P., 2007, Performance assessment of cogeneration systems for industrial district applications. ASME, paper GT-2007-27659.
- [8] Electric Power Research Institute 1997, Technical Assessment Guide, Fundamentals and Methods, Vol.3. EPRI TR – 100281 – V3 – R7.
- [9] Bernal-Agustin, J.L., Dufo-Lopez, R., 2006, Economic and environmental analysis of grid connected photovoltaic systems in Spain. Renewable Energy 31, pp. 1107-1128.
- [10] Europe's Energy Portal, Domestic and Industry Electricity Prices, 2009, <http://www.energy.eu/>