International Energy Agency

COOPERATIVE PROGRAMME ON PHOTOVOLTAIC POWER SYSTEMS

Task 1
Exchange and dissemination of information on PV power systems

Solar Photovoltaic Electricity Applications in France National Survey Report 2006

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Foreword

The International Energy Agency (IEA), founded in November 1974, is an autonomous body within the framework of the Organisation for Economic Cooperation and Development (OECD), which carries out a comprehensive programme of energy cooperation among its 23 member countries. The European Commission also participates in the work of the Agency.

The IEA Photovoltaic Power Systems Programme (IEA-PVPS) is one of the collaborative R & D agreements established within the IEA and, since 1993 its participants have been conducting a variety of joint projects in the applications of photovoltaic conversion of solar energy into electricity.

The nineteen participating countries are Australia (AUS), Austria (AUT), Canada (CAN), Denmark (DNK), France (FRA), Germany (DEU), Israel (ISR), Italy (ITA), Japan (JPN), Korea (KOR), Mexico (MEX), The Netherlands (NLD), Norway (NOR), Portugal (PRT), Spain (ESP), Sweden (SWE), Switzerland (CHE), The United Kingdom (GBR) and The United States of America (USA). The European Commission is also a member.

The overall programme is headed by an Executive Committee composed of one representative from each participating country, while the management of individual research projects (tasks) is the responsibility of Operating Agents. Ten tasks have been established, and currently six are active including a new task concerning PV hybrid systems. Information about these tasks can be found on the public website www.iea-pvps.org.

Introduction

The objective of Task 1 of the IEA Photovoltaic Power Systems Programme is to facilitate the exchange and dissemination of information on the technical, economic, environmental and social aspects of photovoltaic power systems.

An important deliverable of Task 1 is the annual ***Trends in photovoltaic applications*** report. This report gives information on trends in PV power applications in the PVPS member and other countries and is largely based on the information provided in the **National Survey Reports** which are produced annually by each Task 1 participant. The public PVPS website also plays an important role in disseminating information arising from the programme, including national information.

The 2006 national survey report for France presented here is prepared by André Claverie, ADEME, Task 1 participant and includes contribution from Mr Bernard Equer, consultant.

Definitions, symbols and abbreviations

For the purposes of the report, the following definitions and symbols apply:

demonstration Programme: programme to demonstrate photovoltaic (PV) electricity production to various potential users/owners.

EUR: euro currency unit (ISO code). MEUR or M€ means million euro (10^6 EUR).

field Test Programme: programme to test the performance (eg yield and reliability) of photovoltaic (PV) systems/components in real conditions.

final annual yield: total photovoltaic (PV) electricity delivered to the load during the year per kW of rated PV power installed.

grid-connected centralized PV system: power production system performing the function of a centralized power plant. The power supplied by such a system is not associated with a particular electricity customer, and the system is not located to specifically perform functions on the electricity grid other than the supply of bulk power. Typically ground mounted and functioning independently of any nearby development.

grid-connected distributed PV system: system installed to provide electricity to a grid-connected customer or directly to the electricity grid (specifically where that part of the electricity grid is configured to supply power to a number of customers rather than to provide a bulk transport function). Such systems may be on or integrated into the customer's premises often on the customer (demand) side of the electricity meter, on public and commercial buildings, or simply in the built environment. They may be specifically designed for support of the utility distribution grid.

market deployment initiative: set of means to encourage the market deployment of PV through the use of market instruments such as green pricing, feed-in tariffs, tax credits, capital subsidies etc. These may be implemented by government, the finance industry, utilities, etc.

off-grid domestic PV system: system installed to provide power mainly to a household or village not connected to the (main) electricity utility grid(s). Often a means to store electricity is used (most commonly lead-acid batteries). Also referred to as 'stand-alone PV power system'. Can also provide power to domestic and community users (plus some other applications) via a 'micro-grid', often as a hybrid with another source of power.

off-grid non-domestic PV system: system used for a variety of industrial and agricultural applications such as water pumping, remote communications, telecommunication relays, safety and protection devices, etc. that are not connected to the utility grid. Usually a means to store electricity is used. Also referred to as 'stand-alone PV system'.

performance ratio: ratio of the final annual (monthly, daily) yield to the reference annual (monthly, daily) yield, where the reference annual (monthly, daily) yield is the theoretical annual (monthly, daily) available energy per kW of installed rated PV power.

photovoltaic (PV) module manufacturer: organisation carrying out the encapsulation of PV cells in the process of the production of PV modules.

photovoltaic (PV) power: power delivered by a PV module or a PV array under standard test conditions (STC) – irradiance of 1 000 W/m^2, cell junction temperature of 25^{o}C, AM 1,5 solar spectrum – (also see 'Rated power').

photovoltaic (PV) system: set of interconnected elements such as PV modules, inverters that convert d.c. current of the modules into a.c. current, storage batteries (if any) and all installation and control components with a PV power capacity of 40 W or more.

photovoltaic (PV) system market: market for all nationally installed (terrestrial) PV applications with a rated PV power of 40 W or more.

PV: abbreviation of photovoltaic (adj.) or photovoltaics (noun).

rated power: available power delivered by a PV module or array under standard test conditions (STC), written as W.

STC: standard test conditions (irradiance of 1 000 W/m², cell junction temperature of 25 ^{o}C, AM 1,5 solar spectrum).

turnkey price: price of an installed PV system excluding VAT/TVA/sales taxes, operation and maintenance costs but including installation costs. For an off-grid PV system, the prices associated with storage battery maintenance/replacement are excluded. If additional costs are incurred for reasons not directly related to the PV system, these should be excluded. (E.g. If extra costs are incurred fitting PV modules to a factory roof because special precautions are required to avoid disrupting production, these extra costs should not be included. Equally the additional transport costs of installing a telecommunications system in a remote area are excluded).

NOTE – The currency unit used throughout the report is the euro (EUR) and million euro (MEUR). Other units are euro per watt (EUR/W), euro per kWh (EUR/kWh), kilowatt-hour per unit (kW) of rated PV power under STC (kWh/kW).

1 Executive summary

The activity in France during the year 2006 is summarized according to five items: installed PV power, costs and prices, PV production, budgets and energy policy.

• Installed PV power

The overall power of the systems installed in France[1] in 2006, was estimated at 10,9 MW of which 9,4 MW are connected to the grid. A 55 % increase compared to the previous year (7,0 MW total and 5,9 MW grid-connected).

Operational photovoltaic capacity at the end of 2006 is 43,9 MW. This accounts for the annual production of around 44 GWh in electrical energy.

• Costs and prices

System prices continue to decrease with an 8,12 EUR/W for roof added-on PV. Some grid-connected systems with power larger than 10 kW were proposed at the turnkey price of 5 EUR/W. Prices of equipment followed trends of European market. PV modules prices (imported) increased by 20 % due to a demand greater than the offer and increase in feedstock silicon price. Concerning manufacturers of materials, cells and modules, direct production costs decreased due to the increase in volume production and introduction of innovations in the manufacturing processes thanks to R&D results transferred to production.

• Photovoltaic production

Production of photovoltaic cells and modules by Photowatt International Company was of 33 MW in 2006 and has almost reached full production capacity. The Emix production of multicrystalline silicon ingots using the cold crucible continuous electromagnetic casting process has reached 35 tonnes (3 MW equivalent) with one furnace (10 MW equivalent capacity). Tenesol is operating a 15 MW capacity PV modules manufacturing line in its subsidiary Tenesol Technologies. Another subsidiary, located in South Africa can produce up to 35 MW modules. Both factories rely upon crystalline silicon technology.

Thin film hydrogenated amorphous silicon PV modules on glass substrate, are produced by Free Energy at a nearly constant 0,5 MW per year.

• Budgets for PV

The French national R&D budget on PV, as estimated by the Ministry of Research, amounts to 24,2 MEUR including the ADEME-ANR joint programme and the costs of personnel working in public research institutions (for the fraction which is not covered by other national or European contracts). Regional councils are used to subsidize a few local research-industry collaborations adding around 2 MEUR. The budget above does not include exceptional operations like the creation of INES (Institut National de l'Énergie Solaire). The total French public R&D PV budget amounts to 26,2 MEUR. Contributions to market incentives are estimated to amount to about 20 MEUR from which half is coming from regional councils.

[1] France means mainland France and Corsica and the four French overseas departments (DOM) i.e.: Guadeloupe, Guyane, Martinique and Réunion that are large users of photovoltaic energy.

• French policy on Renewable Energies

Important government measures (new feed-in tariff, income tax credit) and initiatives (creation of National Solar Energy Institute, competitiveness clusters on energy) were taken in 2006 following the impulse given by the 2005 law on energy and other legal decisions that followed. Altogether this constitutes a drastic change in the French policy for renewable energies including both a long term perspective with accurate objectives (160 MW in 2010 and 500 MW in 2015) and short terms decisions.

- Feed-in tariff for PV-generated electricity is 0,30 EUR per kWh with a BIPV (building integrated PV) bonus of 0,25 EUR per kWh. Feed-in tariff contracts are signed for a 20 year period and will be revised every year on the basis of a specific inflation index. This measure confirms the governmental and ADEME's policy of promoting the BIPV concept.

- Tax credit amounts to 50 % of PV modules and other equipments costs capped to 8 000 EUR per income-tax paying person. Regional policies can contribute to share the investment cost and to alleviate the financial weight for private persons. Depending on their own policy, regional councils can choose to encourage some specific aspects like building integration or excellent energy management.

- For off-grid isolated dwellings, EDF and ADEME have designed a contract in which most of the PV system investment cost, its maintenance and repair costs are supported by EDF, the owner paying a small part of the total cost (about 5 %) and an annual rent (as an example, the annual rent is 193 EUR for a 1,8 kW system). In rural areas, this regime involves a strong support from the FACE fund.

2 Implementation of photovoltaic systems

2.1 Applications for photovoltaics

Before 2000, photovoltaic applications in France were mainly focused on rural electrification within a first electrification perspective. Grid-connection was not allowed although tolerated in a few dwellings equipped with reverse metering (mechanical) electricity meters. Grid connection is now fully allowed and is being developed at an accelerated pace as well in continental France as in Corsica and overseas French departments (DOM). The main application is roof-top systems either with a few kW (< 10 kW) for private owners or with larger installations (>10 kW) for public buildings like schools. A strong emphasis is placed on building integration (BIPV) as reflected by the high feed-in tariff of 0,55 EUR/kWh.

2.2 Total photovoltaic power installed

Operational photovoltaic capacity recorded in France[2] at the end of 2006 was estimated at 43,93 MW which accounts for the annual production of about 44 GWh of electrical energy. In the year 2006, 10,89 MW have been installed. The installed power of off-grid stand-alone systems decreases, with less than 0,5 MW. This figure includes an activity of replacement of installations at end of life and the reinforcement of existing installations as well as the installation of new equipment. The larger PV system installed on a roof during 2006, 1 MW, is found in the department of Réunion.

There are now several installations in the range over 100 kW. The regional councils have launched calls for projects in 2005 and 2006 representing several megawatts. PV installations or the large majority of them are in urban environment and on buildings.

Table 1 – Cumulative installed PV power in 4 sub-markets in France

Sub-market/ application	31 Dec. 2002 kW	31 Dec. 2003 kW	31 Dec. 2004 kW	31 Dec. 2005 kW	**31 Dec 2006** kW
off-grid domestic	10 437	11 924	13 024	13 844	14 015
off-grid non-domestic	4 862	5 332	5 932	6 232	6 539
grid-connected distributed	1 942	3 817	7 067	12 967	22 379
grid-connected centralized	0	0	0	0	0
TOTAL	17 241	21 072	26 023	33 043	43 933

NOTES
1 – The figures given in Table 1 are calculated as the sum of the installed power as reported by main industrial partners of ADEME having answered the annual questionnaire. They may differ from other and lower estimations based on the total power which has been effectively connected to the grid, as registered by EDF. Due to the fast increase in the number of systems and to the time elapsed between the start of a project and its effective grid connection, the difference in both estimations can be as large as 20 % of the 2006 installed power.
2 – After the important change in energy policy decided by the Energy Framework Policy law in July 2005, year 2006 was a transition year. The law set up a 5-year general programme specifying priorities including increased renewable energy contribution to both thermal and electricity production. However detailed instructions were needed for private investors, installers as well as government agencies to put the law into practice and implement PV systems. These instructions were given by steps, in the Finance Act for 2005 and 2006, and by specific texts. But real application of the new law was not possible before the end of 2006. Thus the effect of these important measures on the total PV installed power is still to come.

[2] France means here, mainland France and Corsica Island and the four French overseas departments: Guadeloupe, Guyane, Martinique and Réunion that are important users of photovoltaic energy systems.

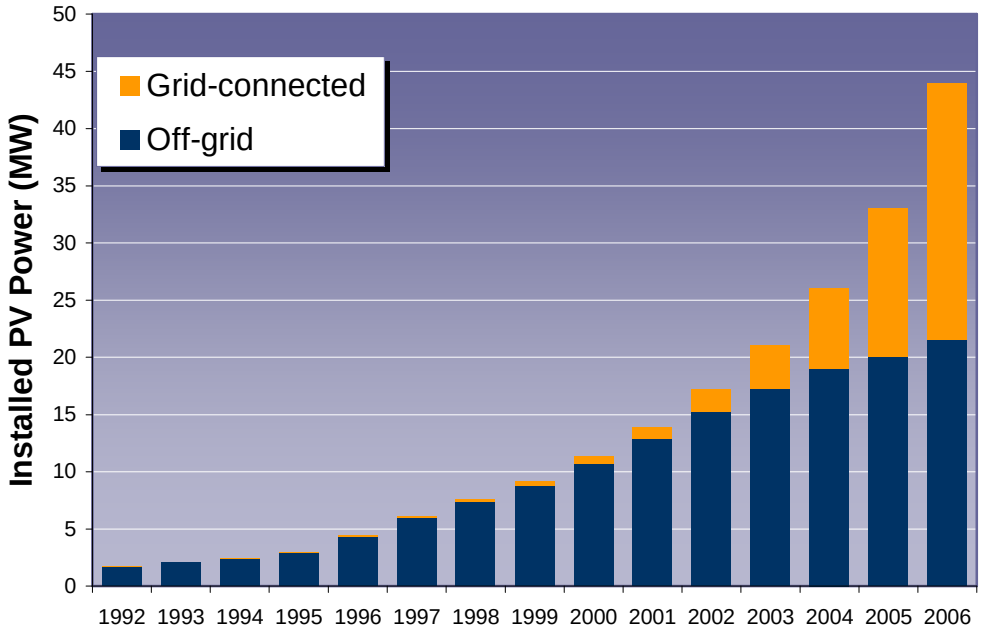

Figure 1 – Cumulative installed photovoltaic power in France from 1992 to 2006

• **The Finance Act** which came into force early 2006 has implemented the new financial subsidy system designed for private individuals installing a photovoltaic array on the roof or façades of their homes. As a result, for private individuals subject to taxation, the fiscal measure consists of reimbursement covering up to 50 % of the costs of the materials (installation costs are excluded). This fiscal measure replaces the subsidies granted by ADEME to private individuals through its regional delegations. A few regional Councils continue to allocate subsidies to private individuals.

For the private or public operators, subsidies are granted on a case-by-case basis as part of calls for projects. In this case, ADEME is insisting on the quality of the architectural integration of the PV modules in the case of new buildings and requires that a strong energy management policy be implemented.

The increase in the French PV feed-in tariff that came into force in the decree published 10 July 2006 (see Table below) constitutes the major event for the French players of the photovoltaic industry this year 2006. In 2005, the tariff stood at 0,14 EUR/kWh in mainland France, a level clearly insufficient for ensuring financial profitability of this type of investment. Price was increased four fold in 2006 for the building integrated PV (BIPV) generators.

Table 1a – Feed-in tariff for photovoltaic electricity in France from 10 July 2006

Feed-in tariff	Mainland France	Overseas departments and Corsica
Basic tariff	0,30 EUR/kWh	0,40 EUR/kWh
Building integration premium	0,25 EUR/kWh	0,15 EUR/kWh
Feed-in BIPV	0,55 EUR/kWh	0,55 EUR/kWh

This feed-in tariff gives a strong boost to the building integration and could allow robust and sustainable growth of the French market on the market segment of BIPV. Up to now, this segment of applications has been poorly developed in Europe and it is a strong added-value creator. The strategy developed by the French authorities through this tariff is to give a strong impetus to innovation in architectural integration, so that in the long run photovoltaics could become a construction material that generates electricity and that is becoming commonplace among the companies from the construction industry. The additional costs generated to date by the integration of the photovoltaic components should in the short-term result in savings made in the implementation of the PV systems.

2.3 National PV implementation highlights in France, major projects

In 2006, the overall power of the systems installed in France during the year is estimated at 10,9 MW the majority of which is connected to the grid, which means a significant increase against the previous year (7 MW).

2.3.1 Major projects

About 60 % of the park of photovoltaic installations is connected to the electricity grid and is currently concentrated in the three overseas departments (Réunion, Martinique and Guadeloupe).

• The larger project is the 1 MW photovoltaic power system installed on the Réunion Island. Located at Le-Port, on the roof of a commercial building, it was dedicated in December 2006 and should supply the Réunion island with 1,3 GWh in electricity per year. The issue of energy independence in the French overseas departments has become a priority for the local political authorities: photovoltaics is associated with a reduction in the energy demand.

• The commune du Moule project in Guadeloupe island is a set of ten PV systems for a total of nearly 0,3 MW, most of it on the roofs of six schools. The PV modules produce up to 400 MWh per year, an important contribution in this island where electricity demand increases by 7 % to 8 % per year. Moreover, the PV modules improve the roof insulation by allowing air to circulate.

• In continental France several grid-connected systems of 100 kW range were installed. The largest building integrated system, is a 10 000 m² dock roof, located in the Paris area. With a power of 0,45 MW the PV array is made of amorphous silicon membranes. The project was accounted for 2005 data (they are not included in 2006 Table 1 data).

2.3.2 Difficulties and delays in implementation

While the new legal framework gave a considerable boost to the development of PV applications in private homes and local community buildings, it is found that many practical problems and difficulties arise in a grid connected project lifetime, from the first decision up to the grid connection. Such a difficulty can be related to the lack of skilled installers resulting from the quickly increasing demand. This should improve slowly with the large efforts on education and training provided by ADEME, INES and industry. Another difficulty is generated by the non-technical and administrative entities that are legally involved in any building construction or modification project and which are not prepared to deal with photovoltaic systems. As a consequence, they show a tendency to ask for excessive guarantees and to delay their agreement. Hopefully, this administrative burden should decrease with PV becoming an ordinary building component. However, the conflict with environment protection measures will continue in the many areas where roofs and façades are part of the historical patrimony.

2.4 Highlights of R&D

2.4.1 The National R&D management

The national photovoltaic R&D programme, formerly managed by ADEME, is now co-managed by ADEME and the new National Research Agency “Agence Nationale de la Recherche” (ANR) created in early 2005. Both agencies launch a common call for proposals every year. Proposals are evaluated by independent experts and a selection is made by a specialist committee involving experts coming half from industry and half from universities. Some twenty-five projects were selected in 2005 and 2006. The projects are lasting from two to three years and cover the crystalline silicon topic, thin films, organic materials and new concepts. Additional projects focus on the photovoltaic system and its components. Project evaluation and review is shared, during their 2 to 4 year lifetime, between both agencies, near market pre-competitive development projects being especially taken into account by ADEME. Once a year, a high level committee establishes thematic priorities to be considered for the next year call for proposals: the last recommendations from this committee were: 1) priority on silicon and thin-films (Si and CIS) industry projects; 2) continue support on new concepts (3rd generation); 3) PV power system (interfaces, storage, BIPV, modelling) and 4) support organic materials research in the framework of European collaborations.

BIPV projects can also be supported by the PREBAT programme, a national programme devoted to R&D for buildings and managed by ADEME and ANR. Similarly, projects that are mostly a proof of concept can be submitted to the ANR basic research programme named “*programme blanc*”.

Among the 25 projects which were selected in the 2005 and 2006 call for proposals, about one third are closely related to industry development projects, either on improvements of existing process and assessment of new technologies. They are summarized below. Some of them were initiated before 2005 in the framework of the ADEME R&D programme. The other two-thirds are long term research projects, investigating new approaches and materials.

ANR and ADEME have launched a new call for proposals in 2007 (www.agence-nationale-recherche.fr and www.ademe.fr) for which seven new research projects were selected.

2.4.2 Industrial technological development and pre-competitive projects

• REDUCOP project (2004-2008) is aimed at cutting the direct manufacturing costs of the photovoltaic cells and modules while improving the module efficiency as well as environment protection and safety. The project gathers the best scientific public teams around Photowatt International and deals with all steps of the process from multicrystalline silicon ingot casting to PV module manufacturing.

• PHOTOSIL project (2005-2008) aims at the production of solar photovoltaic grade silicon (SOG) by the metallurgical route. Based on the FerroPem know-how for high quality metallurgical grade silicon, Apollon Solar patents on a new ingot casting technique, and EPM/CNRS inductive plasma purification experience, PHOTOSIL investigates fusion-segregation and plasma purification to reach the SOG required purity. Located at Bourget-du-Lac, in the vicinity of INES (see § 2.4.4), a 200 tonnes per year pilot is being experimented.

• CISEL/GENECIS (2005-2008) is devoted to the copper indium di-selenide thin film technology and is based on electrodeposition techniques initially investigated at École de chimie de Paris. Low cost and efficiency near 10 % PV modules are expected from this approach. The project is being developed at IRDEP, the research institute created by EDF R&D division and CNRS for this purpose. It is located at Chatou, in the EDF Research centre near Paris.

• ATOS project aims at combining two silicon thin-film technologies, amorphous and microcrystalline, in order to produce tandem cells with improved efficiency. A new, fast deposition technique (ECR PECVD) will be used for the microcrystalline silicon layer and should allow keeping the cost of this step low enough. Saint-Gobain, Total and Solems are partners of this project along with CNRS/LPICM.

• RST project (silicon ribbon on a sacrificial carbon template) is being developed by SolarForce has started in 2003 to build a silicon ribbon pilot based on RST technology. It relies upon a sacrificial graphite ribbon vertically pulled from a melted silicon bath. Two silicon ribbons are obtained after burning off the carbon template. Compared to the many other silicon ribbon processes, this one allows thin layer formation (< 100 µm) and a much better silicon saving together with an excellent productivity due to a high pulling rate.

• NEPSOS/TWIN project attempts to combine a purification phase before fusion-solidification by the continuous electromagnetic casting process developed by EMIX (see § 3.1.2). Plasma purification, directly installed on the head of the continuous casting machine, may allow using upgraded metallurgical grade silicon (UMG) instead of high purity, electronic grade silicon.

• NICE is a project intended to decrease the cost of making PV modules by a fully automated process avoiding the delicate step of soldering connections between cells. The new module technology will be especially attractive with inter-digitized, back contacted cells. Increasing the lifetime of PV modules should be another benefit of these new concepts. The project leader is Apollon Solar.

RST, NEPSOS and NICE projects are funded by OSEO-ANVAR, the agency for funding innovation in the SMEs.

Most of these projects involve private-public partnerships. Involved public research organisations are CEA, CNRS and Universities.

2.4.3 Basic research and long term projects

Two topics have been especially successful in attracting new groups from the best laboratories: organic solar photovoltaic cells and high efficiency ("third generation") cells. These projects have a widely open field of investigation and thus are medium term collaborative programmes rather than specific projects with short-term objectives.

Despite the low efficiencies obtained to date with organic materials, the subject is extremely attractive, mainly because of the large flexibility of organic chemistry. The NANORGASOL project is a national collaboration endeavour between experts in different fields (from the well known organic polymers and molecular crystals up to the more recent fullerene and carbon nanotubes). This group is working with other European network MOLYCELL.

High efficiency, third generation PV, is another collaborative research programme which stems from theoretical considerations about the maximum attainable PV conversion efficiency and investigates different approaches towards an extended spectral sensitivity in the IR part of the spectrum and improved efficiency in the UV part.

2.4.4 Creation of a National Institute for Solar Energy (INES)

The creation of INES (Institut National de l'Energie Solaire) stemmed from a project proposed by the department of Savoie and Rhône-Alpes Region. It was inaugurated in July 2006. INES is composed of three entities: an R&D entity and a centre for education and formation in solar technologies, both closely coupled to a third unit devoted to dissemination of PV and thermal solar energy. INES is installed into provisional buildings on the Savoie-Technolac campus, at Bourget-du-Lac near Chambéry and part of University of Savoie. A European architecture contest has been opened for the future INES building. Research groups from CEA, CNRS and CSTB have started working together in the R&D centre. INES is targeted to reach 250 persons.

2.4.5 National and international conferences held in France

A national PV seminar gathers the French scientific and industry community, once a year since more than 20 years. ADEME and ANR now share the organisation of this important national event. The 2006 edition had to be postponed to March 2007 in order to allow participants to visit the newly installed laboratories of INES. Proceedings of the photovoltaic colloquiums (on CD-ROM) are available (in French only) upon request to ADEME.

ADEME was the co-host of the European conference on hybrid photovoltaic systems and mini-networks (chair: Professor Didier Mayer from *École des mines de Paris*), held in Aix-en-

Provence in May 2006. Several other conferences on thin-films (E-MRS) and on organic materials (ECOS) were held in France during this period.

2.4.6 Clusters of competitiveness

Following the 2004 government call for projects, some 66 clusters of competitiveness have been launched in 2005-2006. These clusters are intended to bring together public and private actors at the regional scale in order to develop highly competitive industry sectors. Three of them focus on renewable energy and involve specific PV projects: Tenerrdis in Rhônes-Alpes region, Derbi in Languedoc-Roussillon region and Capenergies in Provence – Alpes – Côte d'Azur region. Each cluster selects projects and gets funding from the newly created Agence pour l'Innovation Industrielle (AII/OSEO) as well as from ANR, ADEME and local communities.

2.5 Budgets for market stimulation, R&D and demonstration

The national PV R&D budget amounts to 24,2 MEUR (Ministry of Research estimation). It includes two parts: 1) the subventions attributed trough the call for proposals mechanism and which amount to 10 MEUR and 3 MEUR for respectively the ANR and ADEME contributions and 2) the fraction of personnel costs and of basic research costs of public laboratories (CEA, CNRS, universities) which are not covered by national or European contracts. Notice that the call for proposals budget has increased from 4 MEUR per year in 2004 (ADEME's intervention budget and sole backer at that time) to around 12 MEUR per year in 2005 and 2006 (ADEME and ANR intervention budgets).

Regional councils bring another contribution, extremely variable and depending on each Region policy, the south of France Regions being usually more concerned by solar energy. Total contribution of regions can be estimated to 2 MEUR for R&D and about 10 MEUR for market stimulation.

Table 2 – Public budgets for R&D, demonstration/field test and market incentives in France in 2006

(million EUR)	R & D	Demo/Field test	Market
National	24,2	0	10
Regional	2,0	0	10
Total	26,2	0	20

The national PV R&D budgets increase steadily since 2002 as shown in Table 2a. Photovoltaics amounts to about half of the renewable energy R&D budget, which itself is about 6 % of the total energy R&D budget.

Table 2a – National PV and renewable energy budgets since 2002 (MEUR)

R&D	2002	2003	2004	2005	2006
Renewable energy	28,4	25,4	30,7	42,6	52,4
Photovoltaics	15,0	9,4	13,8	21,4	24,2

3 Industry and growth

The French photovoltaic industry relies upon a few motivated players acting since the early 1980s: Photowatt International (multicrystalline silicon ingots/wafers/cells/modules and systems), Apex BP Solar (PV components and systems), Tenesol (previously called Total Energie, PV modules, components and systems) and Free Energy (amorphous silicon modules and systems). Some new firms have recently become involved in this industry: Emix (multicrystalline silicon ingots), FerroPem (feedstock Si material), Apollon (mc-Si casting process and PV module process), Solarforce (silicon ribbon) alongside industrialists manufacturing equipments: ECM, Semco, Vesuvius, etc. and storage batteries manufacturers. Construction components manufacturers also entered the field: Imerys-Toiture, Lafarge-Couverture, Sunland21, Kawneer, etc.

Large groups, either in energy business as EDF and TOTAL or in glass business as Saint-Gobain, have traditionally been involved in PV activities both as stakeholders in medium-size companies, and as sponsors and/or partners in R&D projects (see § 3.5).

3.1 Production of feedstock, ingots and wafers

Table 3 gives a list of main manufacturers of silicon ingots and wafers with type of process and technology. In 2006, there are no producers of silicon feedstock. Two projects in this field are under consideration under the names of Photosil and Silpro.

Table 3 – Production and production capacity information for ingot and wafer producers based in France

Producers	Process & technology	Total annual production	Maximum annual production capacity	Product destination
Photowatt	mc-Si ingots	250 tonnes	300 tonnes	In-house
EMIX	mc-Si ingots	35 tonnes	120 tonnes	Export FR and abroad
Photowatt	mc-Si wafers sc-Si wafers	33 MW (cell equivalent)	35 MW (cell equivalent)	In-house

sc-Si: single crystalline silicon; mc-Si: cast multicrystalline silicon; a-Si:H: thin film amorphous silicon

- **3.1.1 Photowatt International**

Photowatt International S.A.S. is a subsidiary of Automation Tooling Systems Inc. (ATS) a Canadian company. Photowatt is a vertical integrated company located in Bourgoin-Jallieu near Lyon and manufactures multicrystalline silicon ingots, wafers, photovoltaic cells and modules with a 3-shift manufacturing capacity of 35 MW per year. A portion (5 MW) of crystalline silicon cells is shipped to Matrix subsidiary in the USA for module encapsulation.

Photowatt International has been manufacturing PV cells and modules since 1978. The Company manufactures multicrystalline silicon square wafers and cells of 12,5 cm x 12,5 cm (currently in production) and 15 cm x 15 cm. Standard PV cells are blue in colour but Photowatt manufactures brown-grey cells suited for roof tiles integration.

The main features of the production process are the following:

• Ingot casting with a proprietary process based on the Heat Exchange Method. The POLIX™ multicrystalline material is obtained by directional solidification from off-grade electronic silicon scraps (ingot up to 310 kg);

• Wire slicing of ingots into bricks and bricks into wafers, a technology pioneered by Photowatt;

• Automated cell process including surface passivation by plasma enhanced CVD and silk screen printing of front and rear contacts;

• Module manufacturing (glass/glass laminate, or glass/tedlar), aluminium frame (see below).

The company holds R&D contracts from ADEME (4-year, 2004-2008 “REDUCOP” project), ANR and from the European Commission (partner of “Crystal-clear” project). R&D projects include larger and thinner cells, higher conversion efficiency and development of new processes for lowering production costs and recycling production wastes.

- **3.1.2 EMIX**

EMIX has developed a continuous electromagnetic ingot casting technology with a cold crucible based of the work achieved at SIMAP/EPM, a CNRS laboratory located on the Grenoble campus. The 2006 production of 35 tonnes of multicrystalline silicon ingots was obtained with the first casting machine. Two other machines with a 120 tonnes per year capacity should start production in 2007. Each machine produces a continuous ingot with a 34 cm x 34 cm cross-section. Ingots are cut every 50 cm and divided into four 15 cm x 15 cm x 50 cm bricks, ready for wire sawing by clients. The casting is only slightly purifying and thus requires high purity grade feedstock silicon, but an important R&D programme “NEPSOS” has been initiated to include a purification step before casting (see § 2.4.2).

3.2 Production of photovoltaic cells and modules

Table 4.1 lists PV cells and PV modules manufacturers based in France.

Table 4.1 – Production and capacity for PV cell/module manufacturers

Cell/module manufacturer	Technology	Total production (MW/a)		Production capacity (MW/a)	
		Cell	Module	Cell	Module
PHOTOWATT	mc-Si, sc-Si cell and module	33	29	35	40
TENESOL	mc-Si module	0	7	0	15
FREE ENERGY	a-Si:H cell/module	0,5	0,5	1	1
TOTALS		33,5	36,5	36	56

sc-Si: single crystalline silicon; mc-Si: cast multicrystalline silicon; a-Si:H: thin film amorphous silicon

• 3.2.1 Photowatt International

Photowatt module technology is based on glass/glass laminate and on glass/tedlar with aluminium frame. Photovoltaic modules specially designed for utility applications in the range of 80 W, 125 W and 165 W (high insulation modules, façade and roof top modules) are produced to respond to specific demand of customers. The firm offers a 25-year warranty on its PV modules.

Photowatt is under the ISO 9002 quality procedure and the modules are certified within the International Electrotechnical Commission Standard IEC 61215 and European ESTI 503 specification. These module approvals are accepted by electricity utilities. Photowatt was the first company to obtain the PV GAP Quality label (pvgap.org) for its crystalline silicon modules certified under the IEC 61215 international standard.

After focusing for several years on the manufacture of PV cells and modules, Photowatt has decided to come back to PV systems. The company’s approach is to offer standardized systems of 1,6 kW, 3,2 kW and 4,8 kW.

• 3.2.2 Tenesol

Tenesol, formerly Total-Energie is a subsidiary of the oil company Total and electricity utility EDF. Tenesol is a PV system installer and developer of PV system products. Tenesol holds a PV module factory in Cape Town, South Africa (capacity 35 MW per year). A new subsidiary called Tenesol Technologies has started production of large PV modules (200 W range) in Toulouse with a 15 MW PV module annual capacity. The crystalline silicon PV cells are mainly purchased in Germany. The new factory's building integrates a 20 kW BIPV system and was dedicated in 2006.

• 3.2.3 Imerys-toiture

Imerys-Toiture is the first French fired clay tiles manufacturer. Imerys has introduced a new photovoltaic module which features the same height as standard flat interlocking clay tiles and can be inserted into tiled roofs without requiring a modification in the roof frame. The tiles are made from multicrystalline silicon cells and can be delivered with different colours and are marketed as a 1 kW kit (inverter, wiring and modules).

• 3.2.4 Free energy

Free Energy manufactures thin film hydrogenated amorphous silicon PV modules (31 cm x 92 cm). The manufacturing plant, located in Lens (North of France) produces around 0,5 MW with a capacity of 1 MW per year (3 shifts). The amorphous silicon technology is derived from the initial Chronar Corp. process with little modifications. Modules of 5 W, 7 W, 14 W and 19 W are IEC 61646 certified and hold a 10-year guarantee on power output.

3.3 Manufacturers and suppliers of other components

On top of PV cells and modules manufacturers, there are some PV components developers and manufacturers. The industry develops and commercializes multi-function controllers, inverters, storage batteries for PV applications and new products such as high performance water pumping devices and new types of photovoltaic modules adapted to building integration (roof tiles, façade, sunshades, verandas, etc.). Companies' commercial brochures describe very well the characteristics of the PV components and PV systems they commercialize and install.

• PV inverters
Tenesol developed with a European consortium of manufacturers a line of inverters able to accommodate specific features and user needs (remote control, etc.). Selling prices range from 0,5 EUR/W to 0,6 EUR/W according to options. Grid-connection inverters commercialized by other companies are mainly purchased outside of France.

• Storage batteries
Main automotive battery makers are commercialising "solar" types for PV applications: Oldham/Hawker, CEAC/Exide, etc. The main technology is lead-acid, stationary or monobloc type, with a tubular positive electrode (capacity C_{10} ranging from 100 Ah to 900 Ah) or valve regulated (gelified electrolyte or glass mat absorbed) for small capacity. The companies have designed batteries that are more suitable for the charging regimes associated with photovoltaic and hybrid applications.
Saft Company makes and commercializes Ni-metal-hydride and lithium-ion batteries. Some Li-ion accumulators are tested for PV applications within public research laboratory cooperation (CEA/INES) under ADEME contract. The storage batteries must refer to French standards NF C 58400 and/or to the recent NF C 58510 for PV accumulators. In addition, technical rules recommend that for all stand-alone PV systems used for rural electrification and receiving FACE funding, storage accumulators must be installed in a purposely-built shed.

• **Battery charge controllers:** Most of companies active in PV have their own type of multi-function controllers. Tenesol and Apex BP Solar have developed and still continue to improve their custom-made controllers with a central processor unit allowing detailed monitoring of PV systems and pre-payment facility. The controllers are designed to match the specific requirements of storage batteries manufacturers. Such an adaptation prolongs life-time of lead-acid batteries. Along with Tecsol the firms have also developed computer software to carry out data analysis and remote control through satellites or telephone network of the off-grid PV systems they have installed.

• **Supporting structures:** these items are developed by the system integrator companies.

• **Consultancies, associations:** Consulting companies contribute to the benefit of PV activity in France. The companies Cythélia, IED, PHK, Sert, Tecsol, Transénergie and a non-governmental organization Fondem are involved in project management and strategic marketing studies funded by ADEME, the European Commission, development banks and utilities. ASDER, CLER and Hespul, associations along with SER (French Federation for renewable energies) are also very active in promoting PV. SER holds every June a well attended colloquium gathering ministers and decision makers.

• **PV system houses:** In France, there are two PV system companies with an annual turnover superior to 30 MEUR: Tenesol and its overseas Departments subsidiaries (Solelec Caraïbes, Solelec Réunion) and, Apex BP Solar and its overseas departments offices (Caraïbes, Indian Ocean and Guyane). Photowatt is also involved in grid-connected PV systems: its activity is described above. Note that the PV system company Tenesol manufactures crystalline silicon photovoltaic modules in South Africa and in Toulouse (France). Apex BP Solar, a subsidiary of BP-France, makes use of PV modules manufactured by BP-Solar in Spain or other places. Tenesol, Apex BP Solar and Photowatt are also active in installing PV systems abroad. Other active companies are Naps-France, Solarcom-France, Sunwatt-France, 3T France, Conergy France, etc. They make use of any source of PV modules and inverters available on market.

• **Building components:** A few companies develop and commercialize PV modules adapted to buildings: Imerys-toiture, Clipsol, Lafarge-Couverture, Schuco-France, Sunland21, Arcelor/Tenesol, Kawneer/Apex, etc. Roofing membranes are sold by Conergy France and 3T France.

3.4 French industry groups with manufactures outside of France

The two examples below illustrate the growing difficulty to assess national contributions to photovoltaic industry development since most companies (and for France, all companies quoted in this report) are subsidiaries of large international groups. The right scale is clearly the European scale. However, markets are still very different inside European countries. They strongly depend on national policies and in some less apparent way, on national cultures. Indeed, national industries are sensitive to local markets and large groups tend to rely upon their subsidiaries in the countries which most effectively support the market.

• Saint-Gobain – Shell CIS Initiative

Saint-Gobain, one of the largest world glass-maker has been involved in the past into different PV projects, including amorphous silicon thin-films with Solems. The new initiative is a joint project for the construction of a CIS factory. Start of production is expected in 2008 with a 20 MW capacity. Extension to 100 MW is considered. The plant is located in Torgau, in Germany. The CIS technology comes from Shell who bought it from Siemens Solar, which itself bought it from Arco Solar where it was initially developed in the eighties. Saint-Gobain has a large know-how in thin-film deposition on very large glass areas used in building façades.

• Total Photovoltech crystalline silicon cell/module

French petroleum Company Total has a long history with PV industry projects. Total is already commercially active in the field of solar energy through its subsidiary Tenesol. Set up in December 2001, Photovoltech has the backing of three major shareholders: Total (48 %), Suez - Electrabel - Soltech (48 %) and IMEC (4 %). Photovoltech is producing crystalline silicon cells and modules based on IMEC technology. The factory is located in Belgium and has an annual production capacity of about 20 MW.

3.5 System prices

Table 4.2 proposes some typical PV module prices as seen by PV system companies buying modules from a range of manufacturers. In 2006, one can observe a significant increase in module price of the order of 20 %.
PV module manufacturers are not keen on publishing figures including their best price. The trend follows that of European countries active in the field. For large quantity greater than 100 kW an average range of PV module selling price of 3,5 EUR/W to 3,7 EUR/W is circulating.

Table 4.2 – Typical PV module prices (import) in EUR/W

1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
11,62	9,93	8,24	6,55	4,86	4,63	4,41	4,20	4,00	4,20	5,10

Table 5.1 gives turnkey prices (euro per watt, excluding VAT/sales tax) for the various categories of installation. To allow comparison with other countries prices should not include recurring charges after installation such as battery replacement or operation and maintenance. Additional costs incurred due to the remoteness of the site or special installation requirements are not supposed to be included. Nevertheless, that is not the case for rural electrification systems receiving subsidies from FACÉ fund in France.

Table 5.1 – Turnkey prices of typical applications

Category/Size	Typical applications	Current prices EUR/W
OFF-GRID system up to 1 kW	Rural electrification	16,50
OFF-GRID system >1 kW	Rural electrification	12,00
GRID-CONNECTED up to 10 kW	Building added-on PV	7,50
GRID-CONNECTED >10 kW	Building added-on PV	5,00

Table 5.2 gives a trend in average turn-key prices (PV roof added-on and not BIPV) from 1997 to 2006 as seen by a PV system company (does not necessarily reflect national trend).

Table 5.2 – Trends in system prices (PV roof added-on) (EUR/W)

1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
20,40	18,87	17,33	15,80	15,05	14,33	13,65	13,00	11,60	8,12

Following the announcement of new feed-in tariffs and tax-credit measures, the demand for PV modules, components and systems has been growing very quickly. The small number of existing installers has been rapidly flooded with demands that they could not satisfy. A consequence of this situation is a quickly growing number of French Internet commercial sites where PV kits or PV components can be bought.

4 Framework for deployment

Table 7 presents the different measures which are used in France to develop photovoltaic applications.

Table 7– Photovoltaic support measures in France

Support measure	National / Regional / Local
Enhanced feed-in tariffs	National measure
Direct capital subsidies	National subsidy for communities and industry projects; Regional council subsidies for private roof-top investors and industry/communities projects
Tax credits	Applicable for private investors paying

	income tax
Net metering	No more since 2005
Green electricity schemes; PV-specific green electricity schemes; Renewable portfolio standards (RPS); PV requirement in RPS; Investment funds for PV; Net billing; Commercial bank activities; Electricity utility activities; Sustainable building requirements.	No

4.1 New Initiatives

The years 2005 and 2006 were marked by a certain number of events which were conducive to the exploitation of renewable energy sources. French Parliament has passed the Energy Planning Act that sets the guidelines for the energy policy while the government was implementing fresh fiscal and financial measures:

- The Energy Planning Act passed on 13 July 2005 focuses on energy management together with the development of renewable energies; while priority was given to the utilisation of bio-resources and the recourse to solar thermal energy (*Face Sud* Plan). Solar photovoltaic energy (PV) has also been included in the same research package of the law on par with hydrogen and carbon dioxide sequestration;
- The new fiscal measures are aiming at promoting the use by private individuals of materials for heat and electricity generation that are based on renewable energy sources. The tax credit has been set at 50 % for the year 2006 (was 40 % in 2005) ;
- The feed-in tariffs for PV-generated electricity were set at 0,30 EUR/kWh plus a bonus of 0,25 EUR/kWh in case the photovoltaic modules are integrated into the building (continental France). In the French overseas departments and in Corsica, the feed-in tariff has been re-evaluated at 0,40 EUR/kWh plus a building integration bonus of 0,15 EUR/kWh. The decree for the enforcement of the said measures came into force on 10 July 2006.

NOTE – The law of long-term planning of energy investments provides for 160 MW of PV installations in France by 2010 and 500 MW by 2015. In parallel with these measures, the government has overhauled its policy for research funding and created two new means agencies. The ministry in charge of research has created the National Research Agency (ANR, www.agence-nationale-recherche.fr) while the ministry for Industry was setting up the Industrial Innovation Agency (AII, www.aii.fr). Both agencies have placed photovoltaics high on their agendas as priority action themes. As a result, in 2005 and in 2006 the ANR has contributed to significant funds to research projects covering photovoltaics. No photovoltaic projects have yet been selected by the Industrial Innovation Agency (IIA). These projects will have an industrial aspect associated with significant financial backing. The ANR and ADEME have joined forces since 2006 for launching annual calls for research projects. With ANR providing financial backing to fundamental and industrial research projects while ADEME is sponsoring projects covering industrial technology development and pre-competitive development.

4.2 Indirect policy issues

The main policy initiative influencing the implementation of PV power systems in France is the European Commission white paper target of 21 % of electricity generation from renewable energy sources by 2010.

4.3 Standards and codes

In France, installation of stand-alone PV systems and grid-connected systems refer to a set of codes of practices and recommendations issued by UTE, EDF and ADEME. The professional syndicate SER played an important role in developing the regulatory aspects such as connection contracts and electricity purchase contracts:

1. Technical regulations for PV system construction and operation (d.c. working voltage, safety and control devices, supporting structures, etc.) are defined in connection contracts and ADEME's documents such as "*Drafting grid-connected PV systems technical specifications*";
2. Standards and grid interconnection rules for PV systems (protection, islanding, harmonic distortion, power factor, safety, etc.) are defined in DIN VDE126 without impedance control up to 36 kVA. From 30 kVA to 250 kVA rules have to be defined;
3. Building and wiring codes are referring to French Standard NF C15100;
4. International specifications for rural electrification through renewables: EDF, PHK consultancy and UTE under ADEME contract contributed to the development of an International technical specification IEC 62257 within the IEC/TC82 joint working group.

5 Highlights and prospects

The year 2006 was marked by important initiatives that have strengthened photovoltaics within a favourable legal and regulatory framework. One will mention the Energy planning Act that has re-launched energy management and the applications of renewable energy sources, the new solar photovoltaic research programme of the National Research Agency (ANR) and lastly, the publication of new feed-in tariffs for PV electricity and an increase in the income tax credit for private individuals.

The Government has not designed a long-term target for installed PV power capacity though within the Framework energy Law passed July 2005 it is mentioned the target of installing 50 000 solar photovoltaic roofs per year by 2010. For PV, the target is a cumulative installed power of 160 MW in 2010 and of 500 MW in 2015.

Regarding the market for PV applications, the new feed-in tariffs and the environmental concerns should drive private investors whereas, in the past, investments originated mostly from the local communities.

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Annex A Method and accuracy of data

The procedure to gather data was conducted as follows. ADEME, author of National Survey Report 2006, sent a questionnaire to its industry partners participating in PV RTD projects and market deployment initiatives. The questionnaire written in French included the tables provided in the report.

The main obstacle in gathering data is the computation of installed photovoltaic power. The data published here relate to figures provided by the industry. ADEME can not ensure that the amount of kW provided is really installed and operational during the 12 month covered by the enquiry. The published figures do not correspond strictly to data collected by ADEME itself through the list of projects receiving funding during the calendar year. ADEME found difficult in tracking the exact date the PV system is installed and running (can go from 6 to 8 months delay). The situation might improve in future since grid-connected systems will have to get a grid-connection contract from EDF. There is a time shift between the moment the PV system is installed and the connection contract is settled. Moreover the gathering of locally contracted connection and the national computation might take several weeks not to say months. ADEME will study with EDF, SER (Professional Syndicate for Renewables) and other partners means of gathering the data in a more accurate way.

The accuracy of the data is estimated to be ± 15 % for the installed PV capacity and 5 % for the ingot/cell/module production.

The installed capacities by small PV businesses (less than 5 persons), some of them new, which have not answered the questionnaire or which were not approached are not included in the Tables. This will be done in future.

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Annex B Country information

This information gives the reader some background about the national environment in which PV is being deployed. It is not guaranteed to be 100 % accurate nor intended for analysis, and the readers should do their own research if they require more detailed data.

1) retail electricity prices:

   – household : 0,13 EUR/kWh (includes VAT and subscription);

   – commercial: 0,09 EUR/kWh (includes VAT and subscription);

   – NOTE: CSPE tax added to household electricity bill (*Contribution aux charges de service public de l'électricité*): 0,45 eurocent per kilowatt-hour. The tax supports feed-in tariffs mechanisms and other measures of *péréquation*.

2) typical household electricity consumption (kWh):

   household without electric heating 2 500 kWh to 3 000 kWh per year;

   energy efficient household: 1 500 kWh to 1 800 kWh per year;

   household with electric heating: 10 000 to 15 000 kWh per year.

3) typical metering arrangements and tariff structures for electricity customers: two month interval metering, time-of-use tariff.

4) typical household income: 1 500 to 2 300 EUR net per month.

5) typical mortgage interest rate 4 % to 6 %.

6) voltage (household, typical electricity distribution network): 220 V a.c.

7) electricity industry structure and ownership: Production: Électricité de France (EDF) does not hold any more monopoly. Other producers: Direct Energie, Electrabel/Suez, Enercoop, Gaz de France, Poweo, etc. Transport: RTE (*Gestionnaire du réseau de transport d'électricité*). Distribution: principally EDF also various Municipal utilities

8) electricity industry regulator: CRE (Energy Regulation Commission, *Commission de régulation de l'énergie)*. Independent administration in charge of regulating the French electricity and gas markets.

9) price of diesel fuel for household: 0,65 EUR per litre.

10) typical values of kWh/kW for PV systems in parts of France: fixed PV array: 770 kWh/kW for North of France, 1 260 kWh/kW for South of France.

11) cost of PV electricity: 0,50 to 0,60 EUR/kWh (2 kW PV system): 0,30 EUR/kWh to 0,40 EUR/kWh (centralized PV plant). ¤¤¤