



Photovoltaic electricity industry and markets Status and trends in France

1992 – 2002

*Industrie de l'électricité photovoltaïque et marché
Situation et tendances en France*

Technical report

A D E M E



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International Energy Agency

COOPERATIVE PROGRAMME ON PHOTOVOLTAIC POWER SYSTEMS

Task 1

Exchange and dissemination of information on photovoltaic power systems

**Survey report of photovoltaic power applications in
France
2002**

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Contents

Foreword	5
Introduction	6
1 Executive summary	7
..... <i>Résumé en français</i>	8
2 The implementation of photovoltaic systems	11
2.1 Applications for photovoltaics	11
2.2 Total photovoltaic power installed	11
2.3 Major projects, demonstration and field test programmes	12
2.3.1 Off-grid photovoltaic power systems	12
2.3.2 Grid-connected photovoltaic power systems	14
2.3.3 Electricity utility involvement	17
2.3.4 Projects under construction	18
2.3.5 Highlights of research and technological developments (RTD)	18
2.4 Public budgets for market stimulation field test programmes and RTD	20
3 Industry and growth	20
3.1 Production of photovoltaic cells and modules	20
3.1.1 Photowatt International S.A.	21
3.1.2 Free Energy Europe S.A.	22
3.1.3 Solems S.A.	22
3.2 Manufacturers and suppliers of other components	22
3.2.1 PV system houses	23
3.2.2 Battery charge controllers and multi-function controllers	23
3.2.3 Storage batteries	23
3.2.4 Inverters	24
3.2.5 Consultancies	24
3.3 System prices	24
3.4 Labour places	25
3.5 Turnover	25
4 Framework for deployment (non-technical factors)	25
4.1 New initiatives	25
4.2 Indirect policy issues	27
4.3 Standards and codes	27
5 Highlights and prospects	28
Annex A – Exchange rate, method and accuracy of data	30

Foreword

The International Energy Agency (IEA), founded in November 1974, is an autonomous body within the framework of the Organization 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 twenty participating countries are Australia (AUS), Austria (AUT), Canada (CAN), Denmark (DNK), Finland (FIN), 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 Tasks (research projects/activity areas) is the responsibility of Operating Agents. Eight tasks have been established and currently five are active. Information about these tasks can be found on the public website www.iea-pvps.org. A new task concerning urban-scale deployment of PV power systems is being developed.

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

The report dealing with the status of photovoltaics in France in 2002 and 10-year trend has been prepared by:

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Introduction

The study presented here is the national French contribution to the eight edition of the IEA international survey report (1992-2002) on photovoltaic (PV) power applications. The annual international survey report (published September 2003) is a synthesis of the different national survey reports and gives information about development trends in products, markets, applications, major factors affecting PV power system dissemination and national policies related to photovoltaic systems in IEA countries.

The report covers the following main topics:

- The implementation of photovoltaic systems,
- Industry status and growth,
- Framework for deployment,
- Highlights and prospects.

This report provides a picture of the photovoltaic industry and its applications in France covering the years 1992 to end 2002. Data were collected among the actors of photovoltaics in the country including continental France, Corsica Island in the Mediterranean Sea and the overseas administrative departments of *Guadeloupe*, *Martinique*, *Guyane* and *La Réunion*. The data do not take into account activity in French Territories such as New Caledonia and French Polynesia. The authors of the report made their own arrangements with the sources to treat confidential information when requested and ensured that all data were as accurate and correct as possible.

For information, the average annual solar energy available in the different parts of France is as follows: North of France: 1 100 kWh/m² per annum; South of France: 1 600 kWh/m² per annum; Corsica: 1 800 kWh/m² per annum; overseas departments: 1 900 kWh/m² per annum. The average final annual yield of a grid-connected system in continental France is 1 000 kWh per kilowatt of photovoltaic array power (power is measured under IEC Standard test conditions¹).

¹ STC : 1 000 W/m², AM 1,5 solar spectrum, 25 °C photovoltaic cell temperature.

1 Executive summary

The report provides a picture of the photovoltaic industry and its applications in France covering the years 1992 to end 2002. The main stream of photovoltaic (PV) activity in France is that of off-grid power systems. Nevertheless, the ADEME and other public authority partners decided in 1999 to contribute to the funding of grid-connected distributed photovoltaic power systems.

During the year 2002, 3,4 MW of photovoltaic power systems were installed in France and its overseas departments. The annual off-grid PV power system market remains stable at around 2,4 MW per year and that of grid-connected distributed power systems reached almost 1 MW in 2002. The total cumulative installed PV power in France is 17 MW of which 15 MW are off-grid systems and 2 MW are grid-connected distributed PV power systems. This installed capacity represents the annual production of 15 GWh of electricity.

The PV cell/module industry remains very active. The annual production of photovoltaic multicrystalline silicon cells increased by 25 % during the year 2002 to reach 17 MW while the production of amorphous silicon thin film modules increased slightly to go over half a megawatt. Two French companies started introducing on the market photovoltaic modules specifically designed for building integration.

Price of photovoltaic power systems is decreasing towards 20 euros per watt for off-grid systems under public funding and turnkey prices for grid-connected distributed PV power systems vary from 6 to 8 euros per watt according to the level of building integration.

Business turnover of main companies covering the whole field of cell/module manufacturing and PV power system developers/installers, increased 18 % in 2002 to reach 130 million euros.

Due to a Governmental decision taken in 1998, the ADEME increased its annual public budget for the promotion of PV in France to reach around 10 MEUR per year. This new measure allowed a) to reactivate the ADEME's research and technological development programme on PV components, PV systems and applications in collaboration with industry and public research laboratories and b) to grant new demonstration and market deployment projects in both sectors of off-grid PV power systems and grid-connected distributed applications. To implement its PV market deployment programme ADEME makes use of complementary sources of funding such as that of the European Commission, the Regional Councils or the electricity utility EDF.

All together the annual public intervention budget (ADEME, CEA, CNRS, Regional Councils, FACÉ fund) including RTD and market deployment incentives amounted to 20 MEUR in 2002.

The year 2002 was the last budgeted year of the 4-year ADEME PV RTD programme. The projects under this programme will end by mid 2003 and a pool of experts will evaluate the results. The total cost of 4-year PV RTD programme was 72 MEUR of which ADEME granted 47 MEUR. Other contributors were the industry and public organizations like CNRS and CEA. The Atomic Energy Commissariat (CEA) with its GENEC laboratory

based in Grenoble decided in September 2002 along with ADEME to set up a facility of national and international scope capable of developing new technologies and concepts for large area up to 20 cm x 20 cm crystalline silicon cells (objective: efficiency 20 %). The facility will be operational by the end of 2003.

The ADEME's market stimulation programme consists of maintaining the granted volume of 1,2 MW per year for off-grid power systems (installed cost target: 15 EUR per watt) and implementing the new initiative of grid-connected distributed building integrated photovoltaic systems (BIPV). The initiative was launched at the beginning of 2002 with the objective to grant the installation of 20 MW in 5 years. The new BIPV initiative was founded on two favourable measures: a) official publication by the Ministry of Industry of new buy-back rates for photovoltaic electricity: 0,15 euros per kilowatt-hour in continental France and 0,30 euros per kilowatt-hour in overseas departments and b) decision by ADEME, Regional Councils and other partners like the European Commission to grant up to 80 % of the PV system investment.

Two meetings gathering the stakeholders were organized in February and October 2002 by ADEME and the industry partners in order to present and discuss the technical, financial and legal conditions to implement the new BIPV programme. On this occasion ADEME and GENECE presented a compendium of best practices for installing grid-connected distributed PV power systems "*Guide de rédaction du cahier des charges techniques des générateurs photovoltaï ques connectés au réseau*". From his side CSTB (the French Construction industry scientific and technical centre) in partnership with ADEME has explained the first procedures for the technical assessment of the building integrated PV modules. The assessment campaign in view of issuing the Technical Approvals (ATec CSTB) will start in 2003.

A joint group including EDF and SER (a professional syndicate representative of the PV industry) developed both feed-in contracts and technical terms for grid connection of PV power systems. Nevertheless the precise terms of these contracts were not finalized by 2002 but officially released in 2003 after agreement of French Energy Regulation Commission (CRE).

To conclude, the year 2002 showed a significant increase (around 20 %) of the level of production of crystalline silicon cells and turnover of main companies. The new market initiative of installing 20 MW of building integrated PV power systems in five years offers new opportunities for the industry in France.

Résumé de synthèse en français

Ce rapport dresse un état des lieux de la situation du développement technique et économique du secteur des applications de l'électricité solaire photovoltaïque (PV) en France. Le rapport analyse les développements industriels et les mesures prises par les pouvoirs publics pour promouvoir l'utilisation de cette source d'énergie électrique. L'accent est mis sur l'activité de l'année 2002 mais l'étude observe aussi les tendances du développement depuis l'année 1992.

La capacité installée en France² durant l'année 2002 est de 3,4 MW dont presque 1 MW de systèmes raccordés au réseau et 2,4 MW hors réseau, ce qui porte la capacité totale opérationnelle à 17 MW dont 15 MW de systèmes photovoltaïques autonomes en dehors du réseau électrique et 2 MW de systèmes dispersés débitant dans le réseau électrique. Cette capacité totale installée représente la production annuelle de 15 GWh d'électricité.

L'industrie des cellules/modules photovoltaïques a augmenté sa production pour répondre à la croissance de la demande internationale. Ainsi la production des cellules photovoltaïques à base de silicium multicristallin est passée de 13,6 MW à 17 MW (+ 25 %) en 2002 tandis que la production de modules photovoltaïques à base de silicium amorphe hydrogéné en couches minces augmentait légèrement pour dépasser le demi mégawatt.

Le prix moyen des systèmes installés tend vers 20 euros le watt pour les applications hors réseau recevant des fonds publics. En ce qui concerne les systèmes photovoltaïques débitant dans le réseau électrique et recevant des soutiens de l'ADEME, des conseils régionaux et de la Commission européenne le prix clé en main moyen varie de 6 à 8 euros le watt selon le degré d'intégration dans le bâti.

Le chiffre d'affaires des principales entreprises du secteur a progressé de 18 % en 2002 pour atteindre 130 millions d'euros.

Les principales sources de financement public permettant l'installation de systèmes photovoltaïques sont essentiellement le fonds public FACÉ (systèmes autonomes en dehors des réseaux électriques) et les mesures légales de défiscalisation dans les départements d'outre-mer, auxquels s'ajoutent des soutiens complémentaires apportés par les conseils régionaux, l'ADEME, EDF et la Commission européenne (fonds FEDER).

La relance de la promotion des énergies renouvelables décidée par le gouvernement en 1998 dans le cadre d'un contrat État-ADEME a permis de tripler le budget public d'intervention de l'ADEME dès 1999 pour atteindre environ 10 MEUR en 2002. Cette politique a permis de réactiver le programme de R&DT et d'apporter des soutiens financiers pour les opérations d'ouverture des marchés. Dans ce cadre, l'ADEME apporte des aides financières à l'installation des systèmes photovoltaïques qu'ils soient en sites isolés ou raccordés au réseau et fait appel à des contributions financières complémentaires qui proviennent des conseils régionaux, de la Commission européenne ou d'EDF.

² France métropolitaine, Corse et départements d'outre-mer (pas territoires)

Le budget public d'intervention pour la recherche et pour l'ouverture des marchés, incluant les contributions de l'ADEME, du CEA, du CNRS et des conseils régionaux approchait 20 MEUR en 2002.

Pour le programme de RDT PV de l'ADEME, l'année 2002 était la dernière année budgétaire du programme d'action de 4 ans (1999-2002). Les projets seront achevés en 2003 et seront évalués en fin 2003 par un groupe d'experts. Le coût total des projets de recherche sur cette période était de 72 MEUR. L'ADEME a apporté une aide globale de 47 MEUR. Les autres contributions provenant des industriels impliqués dans les projets de recherche et des partenaires publics comme le CEA et le CNRS. En 2002, le CEA et l'ADEME ont décidé de mettre en place au laboratoire GENEC de Grenoble une plateforme technologique qui permettrait de développer des nouvelles techniques industrielles pour la fabrication de cellules photovoltaï ques au silicium cristallin (taille maximum 20 cm x 20 cm. Objectif de rendement de conversion 20 %).

Pour le programme d'ouverture des marchés l'ADEME et ses partenaires financiers apportent des aides à l'investissement. L'objectif est de continuer à installer environ 1,2 MW par an de systèmes PV en sites isolés et, dans le cadre d'une nouvelle initiative décidée en 2002, d'installer, en 5 ans, 20 MW de systèmes photovoltaï ques intégrés au bâti et débitant dans le réseau électrique. Cette initiative s'appuie sur deux mesures incitatives. La première concerne les nouveaux tarifs d'achat de l'électricité photovoltaï que pour des systèmes raccordés au réseau et publiés par le ministère de l'Industrie en mars 2002 : 0,15 euros le kilowattheure en France continentale et 0,30 euros le kilowattheure en Corse et dans les départements d'outre-mer. La deuxième mesure ajoute aux tarifs préférentiels des aides qui permettraient à l'ADEME et à ses partenaires financiers d'apporter jusqu'à 80 % de l'investissement initial.

La nouvelle initiative des applications du PV raccordé au réseau a été présentée et discutée au cours de deux réunions rassemblant les acteurs du secteur photovoltaï que français en février et septembre 2002. À cette occasion, l'ADEME et le GENEC ont présenté le *Guide de rédaction du cahier des charges techniques des générateurs photovoltaï ques connectés au réseau*. D'autre part, le CSTB (Centre scientifique et technique du bâtiment) a expliqué les procédures pour l'homologation des modules photovoltaï ques intégrés au bâti. La campagne d'évaluation pour la délivrance des Avis techniques (ATec CSTB) commencera en 2003. En même temps, le SER (syndicat des professionnels des énergies renouvelables) et EDF mettaient au point les termes techniques des contrats de raccordement des systèmes PV au réseau et précisaient les termes juridiques des contrats d'achat de l'électricité photovoltaï que. Ces deux types de contrats devaient être validés par la Commission de régulation de l'énergie (CRE) dans le courant de l'année 2003.

En conclusion, l'année 2002 s'est distinguée par une augmentation significative de la production des cellules PV et du chiffre d'affaires des entreprises : environ 20 %. L'initiative d'installer en 5 ans, 20 MW de systèmes photovoltaï ques et l'annonce de nouvelles mesures incitatives vont permettre de relancer l'activité en France.

2 The implementation of photovoltaic systems

This section covers the installed photovoltaic (PV) power, and the main demonstration and field test programmes in France. By France it is understood continental France, Corsica Island, and overseas departments (*Guadeloupe, Guyane, Martinique* and *Réunion* Islands and **not** overseas Territories of New Caledonia and French Polynesia in the Pacific).

The photovoltaic power system market considered in the report is defined as the market of all nationally installed (terrestrial) photovoltaic applications with a PV power capacity of 40 W or more. A photovoltaic system consists of photovoltaic modules, inverters, storage batteries (compulsory in off-grid application) and all installation and control components for photovoltaic modules, inverters and storage. Other definitions, symbols and abbreviations can be found in annex B.

2.1 Applications for photovoltaics

The main stream of activity in France is that of off-grid photovoltaic power systems. ADEME, EDF and the Regional Councils along with FACÉ fund and the TAX EXEMPTION contracts in overseas Departments are contributing to the growth of the sector (see 2.3.1 and Tables 2a and 2b).

The installation of grid-connected distributed photovoltaic power systems increased slightly over the years thanks to a series of demonstration projects partially funded by the European Commission and coordinated by an Association of users called “Hespul” (formerly Phebus). By the end of 1999, ADEME decided to contribute to the funding of grid-connected distributed PV power systems and joined a 3-year demonstration project called « HIP-HIP » funded by the European Commission (DGTREN). By the end of 2001 ADEME decided to start a new dissemination programme for this type of application with two promotion measures: buy-back-rate incentives and investment subsidy (programme starting in 2002). See Tables 2a, 2b and section 2.3.2 for further information. In 2002 grid-connected systems accounted for 26 % of installed capacity.

2.2 Total photovoltaic power installed

The total cumulative installed PV power for each sub-market on the 31 December of each year from 1992 to 2002 is given in Table 1.

In 2002, it was installed in France 3 385 kW of PV systems. The off-grid PV installations amounted to 2 415 kW (against 1 937 kW in 2001). The grid-connected installations reached 970 kW (from 364 kW in 2001).

So far, the cumulative installed power installed in France and its overseas departments at the end of 2002 stands at 17 241 kW.

Table 1 – Cumulative installed PV power in France, 1992-2002 (PV array power in kW)

Sub-market/ application	1992	1993	1994	1995	1996	1997	1998*	1999*	2000	2001	2002
Off-grid domestic	1 270	1 460	1 720	2 180	3 160	4 330	5 202*	6 140*	7 416	8 912	10 437
Off-grid non- domestic	480	590	690	720	1 138	1 658	2 230*	2 632*	3 307	3 972	4 862
Grid- connected	1	1	27	40	94	130	199	349	608	972	1 942
TOTAL	1 750	2 050	2 437	2 940	4 392	6 118	7 631	9 121	11 331	13 856	17 241

* In 1998 and 1999 it was not possible to differentiate clearly between off-grid domestic figures and off-grid non-domestic figures (professional applications). It was considered that the off-grid non-domestic share accounted for 30 % of off-grid installations.

2.3 Major projects, demonstration and field test programmes

This section gives information on the current promotion initiatives in France and gives an indication as to their achievements.

2.3.1 Off-grid photovoltaic power systems

In France, the main sources of funding for the deployment of a PV market are ADEME (French Agency for Environment & Energy Management), EDF (*Électricité de France*) within the ADEME-EDF agreement linked to rural electrification FACÉ public fund, the Regional Councils³ and the European Commission.

FACÉ FUND

An important step in the promotion of photovoltaics in France occurred in February 1993, when a collaborative agreement between ADEME and the French Electricity Company EDF (the main electricity utility in France) was signed. The common objective consisted in promoting the use of renewable electricity sources (PV and wind) and particularly PV, for isolated houses where grid extension was demonstrated to be more expensive than the renewable energy solution. This agreement started triggering new business in photovoltaics for rural electrification and in 1995 the access to the financial public fund called "FACÉ" usually devoted to grid extension/reinforcement in French rural areas allowed new promises.

One of the reasons for EDF to embark upon photovoltaics was to offer remote (off-grid) customers with an electricity service financially more economical than pulling and maintaining a line in remote rural areas since cost of an electric line might reach up to 90 000 euros per kilometre.

TAX EXEMPTION CONTRACTS

In 1995, industry and investors took advantage of income tax exemption contracts set up by the French Government for reactivating economy in the overseas departments. The new financial scheme offers three interesting features:

- it brings 20 % of the installed price of the PV system;
- the end-user pays a monthly leasing contract fee of 79 EUR per month for a standard PV system of 1,8 kW;
- operation and maintenance is guaranteed at least for 7 years (up to 15 years if the en-user accepts to continue paying the fee) and includes the replacement of the storage battery park after 5 years.

Moreover, since the avoided production cost of fossil fuel electricity and grid extension costs are high in the French overseas department, ADEME, EDF, the Regional Councils and the European Commission (FEDER structural fund) agreed to jointly grant the PV power systems. The subsidy allocated till the end of 2002 was 10,7 EUR per watt installed and allowed the installation of more than 5 000 PV power systems in overseas departments (the installation rate is around 600 systems of 1,8 kW per year).

LESSONS LEARNED

³ Regional Councils are elected authorities of a group of administrative departments. They have agreements with ADEME within its field of intervention.

The off-grid demonstration and field test programmes in France ended in 1996. The accumulated experience was used to implement market stimulation initiatives aiming at providing users with an electricity service based on renewable energy sources.

The lessons learned from former demonstration and field test programmes are described below and the actions taken are also indicated:

- One must not only sell a PV system but also an energy service and guarantee it for 15 years. This point implies that an electricity utility company or a designated company will take care of the PV system. Action taken: operation/maintenance is compulsory in FACÉ funded installations;
- The user must financially contribute to the initial investment (not less than 5 %) and be closely involved in the utilization of his new source of electricity. Action: users are basically trained by the installer and receive an illustrated technical handbook ;
- An annual fee payment is required. This fee is calculated on the basis of the electricity consumption of an equivalent grid-connected nearby user. Action: the fee is around 15 EUR per month for 1 kW FACÉ funded system and EDF collects it. For TAX EXEMPTION contracts the fee is 79 EUR per month for 1,8 kW system;
- Storage battery replacement after 7 to 8 years must be planned. Action: EDF is taking care of this matter in FACÉ funded systems. The installer deals with battery replacement in TAX EXEMPTION contracts scheme;
- A backup diesel generator set is necessary for domestic systems particularly in continental France. This backup insures the continuing dependability of service and optimizes sizing of PV array. Action: the backup generator is strongly advised in FACÉ funded installations set up in continental France (maintenance cost is the responsibility of user).

The average PV array power of the individual off-grid domestic systems is of the order of 2 kW. Starting at the beginning of programme with PV system of 600 W and reaching now, power in the range of 2 000 W to 3 000 W. An inverter provides 230 V, 50 Hz alternating current in most of the domestic applications and the use of efficient lighting and efficient refrigerator is strongly advised. A backup diesel generator of 5 kVA is frequently used in 2-3 kW PV installations set up in continental France.

Within the FACÉ programme the installed system price did not vary too much during the 1995-1999 period: 27-29 EUR per watt, then decreased towards 20 EUR per watt during years 2000 to 2002. Nevertheless the quality of the service provided increased significantly. For example for safety reasons battery storage units are housed in a specially built shed. One will note that the utility owns the PV generator: maintenance cost of PV system is incurred by the utility meanwhile maintenance cost of diesel backup generator is the responsibility of the user. The monthly electricity invoice sent to the user is in the range of 15 EUR per month for a 1 kW PV system similar to that of any grid-connected customer having the same pattern of electricity consumption. Note that PV systems that are not included in FACÉ fund programme or TAX EXEMPTION contracts are not receiving the same guaranties as explained above and can be installed at a turnkey price of 12 to 15 EUR per watt.

The main funding sources concerning off-grid systems are a) the public FACÉ fund in rural areas of continental France, Corsica and French overseas departments, b) specific subsidies from ADEME, EDF and Regional Councils for systems situated in rural areas not falling under the FACÉ fund and c) TAX EXEMPTION contracts applied in overseas departments.

The FACÉ fund can provide up to 3 MEUR per year for off-grid rural electricity projects coming from renewables (PV, wind and micro hydroelectricity). The FACÉ fund pays up to 65 % of the initial investment, ADEME 13 %, Finance Ministry participates indirectly to 17 % and the customer participates to 5 %. The electricity utility contributes to the equivalent of 20 % of the initial investment to anticipate storage battery replacement after 7 to 8 years and to provide 15-year maintenance costs. TAX EXEMPTION contracts have similar approaches (see 2.3.1).

During the 1995 – 2002 period, 1 315 sites (1 253 kW) were selected for FACÉ funding representing subsidies of 23,7 MEUR (total cost 36,5 MEUR). In 2002, 134,4 kW were selected (72 kW in 2001). Over the considered period, 56 % of the FACÉ systems were installed in continental France and 44 % in French overseas departments. The decision-making procedure of FACÉ fund involves national and local authorities. In certain rural areas where FACÉ fund does not apply it was installed around 30 kW in 2002 (with ADEME, EDF and Regional Councils funding). The TAX EXEMPTION contracts allowed installation of more than 1 MW of off-grid PV power systems in 2002. The ADEME and partners market deployment programme of off-grid PV power systems along the line described above will continue in the future with the plan of installing around 1,2 MW per year.

2.3.2 Grid-connected photovoltaic power systems

Connection of PV power systems to the electricity grid was not a priority item for ADEME and EDF in their dissemination programmes till the end of 1999. Nevertheless a few private initiatives allowed to installing grid-connected distributed PV power systems with the support of the European Commission. The association of users called « Hespul » achieved the installation of around 300 domestic photovoltaic systems amounting to 420 kW at the end of 2002 (www.hespul.org). These projects were carried out under a series of demonstration programmes of the European Commission DGTREN (1993, 1995, 1997, 2001 and 2002 calls for proposals). The level of financial participation of the Commission was up to 35 % of initial investment. For these projects the buy back rate by EDF for PV electricity was made on the basis of net metering (the electric meter works forwards and backwards). Another demonstration project of the EC with a financial contribution of ADEME allowed the installation by the end of 2002 of 450 kW of systems (project called “HIP-HIP”: www.hip-hip.net). The average installed price was 7,5 EUR/W (see Table 2a and 2b).

By the beginning of 2002, a new rate-based incentive for grid-connected PV power system was recommended for systems up to 1 MW. Grid-connected distributed PV electricity will be purchased at a preferential rate of 0,15 EUR per kWh in metropolitan France and 0,30 EUR per kWh in overseas departments. A new set of investment subsidies was proposed by ADEME and became operational by the end of 2002 (see Tables 2a and 2b).

Tables 2a and Table 2b summarize the types and characteristics of major projects in France (continental France, Corsica and overseas departments).

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Table 2a – Summary of major projects in operation in France (part 1)

Project	Objectives, project management, achievements
FACÉ public fund. Off-grid PV power systems for rural electrification	Dissemination programme under ADEME-EDF agreement for off-grid rural electrification. FACÉ and partners subsidises 95 % of investment. Since 1995 the FACÉ fund programme avoided 120 MEUR of line extension and saved 90 MEUR to the community. The project is continuing.
“NON-FACÉ” fund. Off-grid PV power systems for rural electrification	Dissemination programme under ADEME-EDF agreement. Contribution by ADEME, EDF and Regional Councils to off-grid systems situated in areas not covered by FACÉ public fund. The project is continuing on the basis of 30 to 50 kW per year.
TAX EXEMPTION contracts in overseas departments. Off-grid PV power systems and grid-connected	Not a specific initiative to promote PV but the industry takes advantage of this financial incentive to invest in domestic off-grid PV power systems in overseas departments. Financial contribution comes from private investors. This financial scheme is continuing and the industry applies it since end of 2002 to grid-connected distributed PV power systems.
EUROPEAN COMMISSION demonstration programme. EC, ADEME and Regional Council co-funding. Grid-connected distributed PV power systems	<p>Demonstration projects of the European Commission (DGTREN).</p> <ul style="list-style-type: none"> - Projects coordinated by HESPUL users’ association (calls for proposals 1993, 1995 and 1997 amounting to a total of 280 kW of grid-connected distributed systems « PV roofs »). New EC funded projects started in 2001: <ul style="list-style-type: none"> “PV-SALSA” (Service assurance for large social acceptance of PV stand-alone and grid-connected systems. 70 kW installed in 2001). "PV-STARLET" in cooperation with IMERYYS TOITURE (420 kW of PV tiles to install in France by end 2004). "UNIVERSOL" (PV on school buildings. 345 kW to be installed in France by end 2004). Installations at 6 EUR/W. - Project coordinated by ADEME: “HIP-HIP”. 3-year joint demonstration project. This project accepted in 1999 became operational by 2000. 450 kW were operational in France in 2002. 35 % of EC subsidy applies to a maximum installed cost 5,45 EUR per watt at the end of project.
ADEME’s new market stimulation initiative. Building integrated grid-connected distributed PV power systems	Starting 2002, a 5-year dissemination project aiming at installing 20 MW of building integrated grid-connected distributed PV power systems. Support of selected projects restricted to a maximum of 4,6 EUR per watt (basic grid-connected PV system) and a maximum of 6,1 EUR per watt (grid-connected system with safety storage in overseas departments). Ceiling of 80 % of turnkey price. Energy efficiency measures (demand side management) are recommended to be applied.

Table 2b – Summary of major projects in operation in France (part 2)

Project	Total power installed	Total costs	Funding	Utility funding (%)	Other funding (%)
FACÉ public fund (off-grid systems)	1 253 kW 1 315 sites	36,5 MEUR (8 years)	FACÉ: 65 %, Finance Ministry (VAT): 17 %, ADEME: 13 %	EDF equivalent of 20 % of total investment for 15-year maintenance and storage battery replacement	User: 5 % (user pays the back up diesel generator and efficient appliances and a monthly fee of 15 EUR per kW installed).
“NON-FACÉ” fund (off-grid systems)	Average of 30 kW per year	0,6 MEUR per year	ADEME: 35 %, Regional Councils up to 25 %	EDF: 35 %	User: > or = 5 %.
TAX EXEMPTION contracts in overseas departments (off-grid systems)	1 MW per year	25 MEUR per year	ADEME + Region + European Commission (FEDER fund): 24 %, Finance Ministry: 17 %	EDF: 18 %	User: 41 % User pays a loan of 79 euros for 1,8 kW system and per month.
EUROPEAN COMMISSION demonstration (grid-connected distributed PV power systems)	- 600 kW since 1994 (On-going projects) - 450 kW 2000-2002 (ended)	4,2 MEUR Several projects coordinated by HESPUL 3,5 MEUR Proj. Hip-hip coordinated by ADEME	European Commission: 35 %, Regional Council: up to 30 %. Since 1999 ADEME contributes up to 15 %	PV electricity purchased on a net metering basis (0,095 euro per kWh) but new projects should be included in the system of new rates published in March 2002: 0,15 EUR per kWh in continental France and 0,30 EUR per kWh in Corsica and overseas departments	User: 20 % to 50 %.
New ADEME’s market stimulation initiative (Building integrated grid-connected distributed systems)	20 MW in 5 years 2002-2006	120 MEUR	ADEME, Regional Councils, EC FEDER and Finance Ministry: up to 80 % of investment	PV electricity purchased at new rates published in March 2002: 0,15 EUR per kWh in continental France and 0,30 EUR per kWh in Corsica and overseas departments	User : will pay at least 20 % of investment

2.3.3 Electricity utility involvement

Photovoltaic energy is principally considered by the French electricity company Électricité de France (EDF) as a potential source of electricity in remote rural areas where it is demonstrated that it is more expensive to pull a power line than to set up a PV power system (in French rural areas cost of a line can be up to 90 000 EUR per kilometre). In 1993, ADEME and EDF signed an agreement to promote the use of PV power systems in rural areas. Meanwhile, EDF decided by the end of 1995 to start up a PV RTD programme covering both PV cell technologies and PV system components. A global involvement of 4 MEUR per year was then announced. Three projects were implemented: systems and standardization, materials and processes (the “CISEL” project investigates electrodeposited polycrystalline Cu-In-Ga-Se thin film PV modules) and management of rural electrification in developing countries.

EDF is not operating any large-scale grid-connected PV power plants. However, in the frame of the national rural electrification programme sponsored by ADEME and EDF, the French electricity utility promotes the use of photovoltaic energy for in remote locations. In mainland France, the PV generators are operated and maintained by EDF. Long-term contracts (so-called concessions) between EDF and the municipalities define the terms of the provided service, prescribe battery replacements, etc. The cost of the energy sold to the end-user is calculated based on how much a user would have to pay for the equivalent service if he was connected to a local electricity grid. During the past decade, more than 5 000 remote households have been equipped with photovoltaic energy systems.

To follow up the projects where EDF and ADEME are involved, a database called ISIS (www.base-isis.com) was developed in co-operation with Technosolar, a French association of installers. The database is designed to store information about off-grid PV systems. Each site is described by more than 300 different data. The objective is to improve knowledge about users, get technical feedback on system sizing and about users' profiles and energy needs.

Regarding the development of the grid-connected distributed PV power systems in France, EDF has elaborated, together with the PV industry, the Ministry of industry and the Energy Regulation Commission CRE (www.cre.fr), the institutional frame for on-grid operation of PV systems. Both feed-in contracts and technical rules for grid connection have been specified and released in 2003. According to the French feed-in law, EDF purchases PV electricity at a rate of 0,15 EUR per kWh in mainland France and 0,30 EUR per kWh in the four French overseas departments and Corsica (starting from the 1 January 2003, the tariffs decrease by 5 % annually).

Since the year 2000, EDF is being involved in the development of International Standards within a newly formed joint coordination group of the International Electrotechnical Commission (IEC). This implication is described in section 4.3.

In 2001, EDF has launched the ACCESS (Access to electricity and to services) programme. ACCESS consists in developing and implementing in the developing countries villages remote from the grid, a group of profitable decentralized rural electrification projects. Each project leads to the creation of a DSC (Decentralized Services Company), a local structure for the exploitation of the services provided to the concerned populations. The ambition of ACCESS by the end of 2003 is to allow access to electricity for more than 100 000 people within a selection of countries (Mali, Morocco and South Africa).

It should be noted that the collaboration agreement between ADEME and EDF has been renewed in June 2000, and a special section on energy efficiency issues has been included. Negotiations are under way to extend the agreement beyond 2003.

2.3.4 Projects under construction

The main stream of activity remains the installation of off-grid PV power systems for rural electrification for which the main promoters are: ADEME, EDF, Regional Councils and local authorities through FACÉ fund and Tax exemption schemes. The European Commission (through FEDER fund) contributes also to financial incentives for projects in the French overseas departments.

All together ADEME and its financial partners plan to support around 1,2 MW of off-grid photovoltaic power systems per year.

The novelty during the years 2000-2002 concerns distributed grid-connected domestic PV power systems. ADEME started in cooperation with the European Commission (DGTREN) a targeted demonstration programme on distributed building integrated photovoltaic systems (project called “HIP-HIP”, “House Integrated Photovoltaics – High-tech in Public”) aiming at the installation in Metropolitan France of 450 kW. The overall objective of the EC project was to install 2,7 MW in six European countries (AT, DE, ES, FR, IT and NL). A beneficial exchange of experience occurred with the five partner countries on the following issues: end-users issues, impact on the grid connection, non-technical barriers, building integration and certification (see Tables 2a and 2b). A brochure describing the achievements of the HIP-HIP project was published by ADEME in May 2003 “*L’électricité solaire dans le bâtiment – Retour d’expérience du projet européen Hip-Hip - Avancées et réalisations*” (downloadable from www.hip-hip.net).

Meanwhile the HESPUL User’s Association has been pursuing installation of PV roofs with financial support of the European Commission Directorate general DG TREN projects with two new projects in 2002 “PV STARLET” and “UNIVERSOL” (see Tables 2a and 2b).

During the year 2002, the ADEME has prepared an aid system aiming at the deployment of grid-connected distributed photovoltaic systems. In this context, photovoltaic systems are the subject of support to a maximum of 4,6 EUR per watt for basic grid-connected distributed PV power system and a maximum of 6,1 EUR per watt for grid-connected distributed PV power system with safety storage. This includes potential subsidy of the European Commission and anyway less than 80 % of installed turnkey price.

These aid rates will decrease as of 1 January 2005, at 3,8 EUR per watt (basic grid-connected) and 4,9 EUR per watt in the case of a grid-connected PV system with safety storage. A power ceiling will be applied, that is to say 5 kW for individuals and 15 kW in the community/tertiary sector, beyond these ceilings, a case-by-case analysis will be carried out.

The technical specifications established by the ADEME determine the design, size and installation rules, as well as the safety rules and the technical measures for integration into the building to be taken into account.

2.3.5 Highlights of research and technological developments (RTD)

Together with its industrial and public partners, ADEME has implemented projects of research and technological development (RTD) on the PV components and the systems.

The objective is to cut the component's costs as well as the systems' operating costs, increase their performance, quality, reliability and building integration.

The year 2002 was the last budgeted year of the 4-year ADEME PV RTD programme. The projects under this programme will end by mid 2003 and a pool of experts will evaluate the results. The total cost of 4-year PV RTD project was 72 MEUR of which ADEME granted 47 MEUR. Other contributors were the industry and public organizations like CNRS and CEA. Every year the ADEME gathers in November around 100 researchers to discuss the advances in the field of materials and processes for photovoltaic cells. The topics selected and the partners involved in ADEME's RTD programme are the following:

- Materials and processes for the industrial manufacturing of multicrystalline silicon photovoltaic cells: « PV-16 » 4-year project 1999-2002, ending mid 2003 (Photowatt International in cooperation with the public CNRS laboratories);
- Materials and manufacturing processes of thin film photovoltaic cells:
 - 1) Monocrystalline silicon film: « Succes » project (CEA-GENEC and INSA Lyon).
 - 2) Heterojunctions based on amorphous and crystalline silicon: « Hermes » project (CEA-GENEC and CNRS).
 - 3) Cells based on Cu-In-Ga-Se prepared by electrodeposition: « Cisel » project (EDF-R&D, CNRS and Saint-Gobain Recherche).
 - 4) Cells based on organic polymers (CEA-LCO, CNRS and Universities);
- Engineering of the photovoltaic systems: management and control of the energy flows, converters, inverters (Apex BP Solar, Total Énergie, Transénergie, CEA-GENEC, Armines, CNRS) ;
- Storage batteries adapted to the photovoltaic applications: charge/discharge protocols, monitoring of ageing, reliability test, measure of the charge conditions (CEAC/EXIDE, Apex BP Solar, CEA-GENEC, CNRS) ;
- Multisource, stand-alone village electrification systems for individual uses, water pumping (Transénergie, Total Énergie, Apex BP Solar, Armines, CEA-GENEC) ;
- Accompanying studies on the testing, return of field experiences, global management of the network of PV systems, granting of a concession, reliability of the systems and development of standards (CEA-GENEC, Armines, EDF R&D, PHK, IED, FONDEM, SERT, Costic, etc.).

In 2001 the French Atomic Energy Commissariat (CEA) presented a new policy in the field of renewable energies through the creation of a research programme dedicated to the new technologies of energy. As a consequence the GENEC laboratory has integrated into its missions new research works on the photovoltaic cells (see above) and has increased its headcount. The close collaborations established between the public research organizations CEA and CNRS on new projects are giving a new impetus to the French photovoltaic research. Furthermore CEA and ADEME decided in September 2002 to set up a facility of national and international scope capable of developing new technologies and concepts for large area (up to 20 cm x 20 cm) crystalline silicon cells. The facility is based at GENEC laboratory in Grenoble (www-drt.cea.fr/genec.fr) and will be operational by the end of 2003.

For its part, in 2002, the CNRS has concluded the ECODEV multidisciplinary research programme on energy and the environment, and begun a discussion on how to pursue its involvement in the photovoltaic sector (www.imp.cnrs.fr/energie).

The *Électricité de France* (EDF) company has been mobilising on two activities. The research works on the Cu-In-Ga-Se thin films obtained by electrodeposition in cooperation with Saint-Gobain Recherche and the CNRS, and the international standardization file (see 4.3).

Regarding the development of the grid-connected distributed PV power systems in France, EDF with the professional syndicate SER (*Syndicat des énergies renouvelables*), the Ministry of Industry and the Energy regulation Commission (CRE) elaborated the institutional frame for the grid-connected operation of photovoltaic systems. Both feed-in contracts and technical terms for grid connection have been specified and were to be released by June 2003.

2.4 Public budgets for market stimulation field test programmes and RTD

Table 3 gives public budgets for research and technological development (RTD), and market deployment incentives (public subsidies, fiscal incentives) on the national level, and on the regional level.

Table 3 – Public budgets for RTD and market incentives 2002 (MEUR)

	RTD 2002	Market stimulation initiatives 2002	Total (MEUR)
ADEME	4,8	5,6	10,4
CNRS, CEA, Armines Universities	4,9	-	4,9
FACÉ FUND	-	2,2	2,2
Regional Councils	0,1	2,3	2,4
Total	9,8	10,1	19,9

3 Industry and growth

3.1 Production of photovoltaic cells and modules

In France there are three manufacturers of photovoltaic PV cells and modules:

- Photowatt International S.A. who started manufacturing crystalline silicon PV cell and modules by the end of the seventies,
- Free Energy Europe S.A. who started in 1986 manufacturing thin film hydrogenated amorphous silicon modules and,
- Solems S.A. who started in 1983 fabrication of small size thin film hydrogenated amorphous silicon modules for original equipment manufacturers.

The photovoltaic cell production stagnated to a level of 2 MW per year over the first 3 years of the 1992 – 2000 period then shipments grew drastically to reach more than 17 MW in 2002. Table 4 gives names of cell/module manufacturers, type of cell material; total production of cells and modules, production capacity (three shifts).

Standard photovoltaic modules of 10 W to 165 W are manufactured in France. The PV modules meet utility needs for their applications. More recently power modules for building integration were developed by two companies.

Table 4 – Annual production and production capacity information

Cell/Module manufacturer	Technology	Total Production (MW)				Maximum production capacity (MW)
		PV cell ³⁾		PV module		
		2001	2002	2001	2002	2002
Photowatt International	mc-Si ¹⁾	13,6	17,0	5,0	8,0	25 MW PV cell 10 MW PV modules
Free Energy Europe	a-Si:H ^{2), 3)}	-	-	0,5	0,5	1 MW PV modules
TOTALS		13,6	17,0	5,5	8,5	

1) mc-Si - cast multicrystalline silicon

2) a-Si:H - thin film hydrogenated amorphous silicon on glass substrate

3) differentiation between PV cell and PV module has no relevance for thin film amorphous silicon since cells and modules are integrated within the same substrate.

3.1.1 Photowatt International S.A.

Photowatt International (www.photowatt.com) is a vertical integrated company based in Bourgoin-Jallieu near Lyon. The company manufactures multicrystalline silicon ingots, wafers, cells and modules with a 3-shift manufacturing cell capacity of 25 MW per year (20 MW in 2001).

The main steps in the production process are the following:

- 1) Directional solidification of multicrystalline silicon ingot up to 280 kg (feed-stock silicon comes from off-grade electronic silicon scraps),
- 2) Slicing of wafers with wire saws with a reduced kerf loss (wire sawing has been effective for several years and Photowatt is one of the rare if not the single company able to slice 200 µm-thick wafers with a high volume production),
- 3) Cell fabrication: junction fabrication through diffusion doping of phosphorus oxychloride ; surface passivation through plasma enhanced CVD of silicon nitride ; silk screen printing of front and rear contacts,
- 4) Module manufacturing (glass/glass laminate, or glass/tehdar), aluminium frame.

The company innovated on several fronts such as "POLIX"TM directional solidification ingot casting (ingot weighting up to 280 kg) and wire sawing of thin wafers (down to 150 µm). RTD projects include larger and thinner cells, higher conversion efficiency (silicon nitride, 15 % range...) and development of new processes for lowering production costs. The company holds RTD contracts from ADEME (4-year 1999-2002 "PV-16" project) and from the European Commission.

Photowatt International has been manufacturing PV cells and modules since 1978. The company manufactures multicrystalline silicon square wafers of 12,5 cm x 12,5 cm (currently in production) and 15 cm x 15 cm, and PV cells of the same size. Standard PV cells are blue in colour but at the demand of customers Photowatt manufactures brown-grey cells suited for roof tiles integration. The firm offers a 25-year warranty on its modules. 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 is under the ISO 9002 quality procedure. Photowatt has been the first crystalline silicon manufacturer to receive at the beginning of 2003 the quality label PV GAP.

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.

Ingots, wafers, cells and modules are produced in Bourgoin-Jallieu facility near Lyon. Capital had changed hands in April 1997 when the company was acquired by Automation Tooling Systems (ATS) from Canada.

3.1.2 Free Energy Europe S.A.

Free Energy Europe (www.free-energy.net), manufactures thin film hydrogenated amorphous silicon PV modules. The manufacturing plant located in Lens (North of France) has a manufacturing capacity of 1 MW per year (3 shifts). The main steps in the production process are the following:

- 1) CVD process for depositing transparent conducting electrode (TCO) on a glass substrate. The company also buys TCO substrates elsewhere;
- 2) Laser scribing of TCO and a-Si;
- 3) Vertical single plasma enhanced chemical vapour deposition (PECVD) monochamber for single a-Si junction (modified Chronar Corp. process);
- 4) Metal electrode deposition by sputtering with mask;
- 5) PV module encapsulation (glass/glass laminate, polymer frame).

The company manufactures glass/glass laminate, polymer frame (size: 31 cm x 92 cm) PV modules having a STC initial power of 14 W, 12 V (smaller sizes of 5 W and 7 W are also produced). A new tandem junction module of 19 W has been introduced in pre-production in 2002 and should receive the IEC 61646 certification in 2003. Warranty is 10 years. The company commercializes a range of product systems like home battery chargers and solar home kits mainly used for rural electrification in developing countries and in stand-alone applications in industrialized countries.

The reliability of PV modules is guaranteed by their unique polymer encapsulation and framing method, which was developed with financial support from ADEME. The company participates to two R&D projects funded by the European Commission.

3.1.3 Solems S.A.

Solems S.A. (www.solems.com) manufactures custom-sized thin film amorphous silicon 30 cm x 30 cm PV modules addressing mini-power applications up to 5 watts mainly for original equipment manufacturers. The PECVD process is using a vertical single chamber developed by the company. Glass coated with transparent conducting electrode is purchased elsewhere. The 2-shift production capacity is around 100 kW per year. Further details are not given since the products do not fall under the scope of this report.

3.2 Manufacturers and suppliers of other components

In France there is a PV related industrial activity on PV components and PV systems. Battery charge controllers, multi-function controllers, storage batteries for PV applications, inverters for stand-alone PV systems, and new products such as high performance pumping devices are both developed and commercialized. PV companies' commercial brochures describe very well the characteristics of the PV components and PV systems. They are available on the companies' websites (addresses are given below). In 2002 it is worth noting that two companies got involved in the development and commercialization of new

types of photovoltaic modules adapted to building integration: the company CLIPSOL (www.clipsol.com) specialized in solar thermal heating systems developed with Total Énergie a building integrated PV module. The new product is commercialized under the name "CLIPSOL TGD".

The company IMERYYS Toiture (www.imerys-toiture.com) the first French fired clay tiles manufacturer developed a new photovoltaic tile which features the same size as a standard tile. An EC demonstration project called "PV Starlet" coordinated by the association Hespul (www.hespul.org) aims at involving European tiles manufacturers, roofers and building material dealers. IMERYYS Toiture is one of the partners of the project. A small company called Sunwatt-France (www.sunwatt-energy.com) has developed and commercializes the so-called "Megatuile" which is a rainproof PV roof cover tile of large size (custom designed).

3.2.1 PV system houses

In France, there are two PV system companies with an annual turn-over superior to 20 MEUR: Total Énergie (www.total-energie.fr) and its overseas departments subsidiaries (Solelec Caraï bes, Solelec Réunion), and Apex Bp Solar (www.apex-bpsolar.com) and its overseas departments offices (Caraï bes, Indian Ocean and Guyane). Note that the PV system company Total Énergie manufactures photovoltaic modules in South Africa: The Tenesa Company has a photovoltaic module capacity of 8 MW per year. Apex BP Solar, a subsidiary of BP-France, makes use of PV modules manufactured by Bp-Solar in Spain or other places. Total Énergie and Apex Bp Solar are also active in installing PV systems abroad. Another company Naps-France (www.napssystem.com), connected to NAPS International (Finland), is also operating in France but makes most of its business abroad. Naps-France uses PV modules manufactured in Sweden. Other active companies are Sunwatt-France, Solarcom, Sert, etc.

3.2.2 Battery charge controllers and multi-function controllers

Most of the companies active in PV have their own type of multi-function controllers. Total Énergie 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. Along with Tecsol they 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.

3.2.3 Storage batteries

There are two main storage battery manufacturers with a specific experience in the PV sector: CEAC/Exide and OLDHAM. The main technology is lead-acid, stationary or monobloc type, with a tubular positive electrode (capacity C10 ranging from 100 Ah to 900 Ah) or valve regulated (gelified electrolyte or glass mat absorbed) for small capacity. The companies have designed storage batteries that are more suitable for the charging regimes associated with photovoltaic and hybrid applications. Furthermore, CEAC/Exide Company is developing with a PV system company, CNRS/University Laboratories and CEA-GENEC new concepts for managing storage batteries used in PV applications. Testing programmes of accelerated ageing of storage batteries are taking place at GENEC laboratory (www-drt.cea.fr/genec), a CEA (Atomic Energy Commissariat) unit.

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 systems receiving FACÉ funding, storage accumulators must be installed in a purposely-built shed.

3.2.4 Inverters

For off-grid systems the company AINELEC develops and commercializes sine-wave inverters for PV/diesel village power systems. So far there are no PV specific inverter manufacturers for grid-connected PV power systems: the situation is changing since two PV system companies are developing new inverters with original integrated characteristics adapted to a range of grid-connected distributed PV systems including those featuring safety storage batteries and backup diesel generator.

3.2.5 Consultancies

Consulting companies contribute to the added value of PV activity in France. The companies Transénergie, Sert, Cythélia, PHK, IED, Tecsol, Erdyn Consultants, Sud Consulting and Fondem (a non-governmental organization) are involved in project management and strategic marketing studies funded by ADEME, the European Commission, development banks and utilities. The HESPUL and CLER associations are also very active in promoting PV.

3.3 System prices

Table 6 gives turnkey prices (excluding VAT) in euros per watt for typical off-grid PV system and typical grid-connected PV systems.

Table 6 – Turnkey prices of typical applications (EUR·W⁻¹)

CATEGORY/ RANGE (PV array power expressed in kW)	TYPICAL APPLICATION	PRICE (EUR·W ⁻¹)
OFF-GRID domestic 1 kW – 4 kW	Permanent dwellings (2 kW) with a 15-year guarantee of service (FACÉ funding). The price includes storage battery replacement and a battery shed.	16-24 EUR·W ⁻¹
OFF-GRID non-domestic 1 kW to 5 kW	Professional application (telecommunication relay, etc.), (guaranties and overall service are different from FACÉ funded systems).	12 to 15 EUR·W ⁻¹
GRID-CONNECTED distributed 1 kW range	Domestic grid-connected PV roof top in metropolitan France	5,5 to 8,0 EUR·W ⁻¹

The factory price breakdown of an off-grid PV power system is as follows: 30 % for the PV modules, 30 % for storage batteries and 40 % for balance of system components. When receiving public funding, PV power systems must refer to the technical specification handbook untitled « *Specifications for the use of renewable energies in rural decentralised electrification* » published by ADEME and EDF in October 1997, under revision for publication in the year 2003.

3.4 Labour places

The number of people involved in photovoltaics in France is estimated at 580 persons (companies having contributed to the statistical data plus public research including CNRS, CEA and universities). The figure is slightly up compared to the year 2001: a bit more in public research due to the involvement of CEA and EDF in PV research and new jobs in PV system companies. The figure breaks down according to the following categories:

- Research and development (not including companies): 75 persons;
- Manufacturing of PV system components, including R&D: 340 persons;
- All other, including electricity company, installation companies, etc.: 165 persons.

3.5 Turnover

Total business turnover of main PV system companies (cell/module manufacturers and PV system houses mentioned above) is 130 MEUR in 2002 (18 % increase since 2001).

4 Framework for deployment (non-technical factors)

4.1 New initiatives

In France, several elements have created a political and regulatory context that is favourable to the development of the renewable energies:

- The European directive on the electricity from the renewable energies (RE) has been definitively adopted in September 2001. It sets the contribution of the renewable energies for France which should increase from 15 % in 1997 to 21 % in 2010;
- The National scheme for the improvement of energy efficiency (PNA2E) has been implemented by ADEME upon the government's request. The implementation of the FIDEME special fund (listed in the PNA2E) for subsidies granted to the SMEs became real in 2002 and after obtaining the agreement of the European Commission;

- New purchasing rates proposed in October 2001 and officially published by the beginning of 2002 by the Ministry of the Industry for photovoltaic electricity: 0,15 EUR per kilowatt-hour in mainland France and 0,30 EUR per kilowatt-hour in the overseas departments and Corsica island, these are regions where electricity is expensive to produce;
- Within the framework of the «electricity utility company modernization» law, a regulating authority has been established: the Energy regulation commission (CRE). It has the task of monitoring the opening of the electricity market in view of guaranteeing a fair competition and seeing to service quality and electricity costs.

The level of ADEME's public budget was confirmed stable between 2000 and 2002 after a significant increase in 1999.

In addition, during the year 2001, the CEA (Atomic Energy Commissariat) decided to be more involved in renewable energy research. A Department of "new energies technologies" (DTEN) was created to deal with hydrogen, fuel cells, electrochemical storage and photovoltaics. On top of the current activity of CEA-GENEC photovoltaic systems laboratory in Cadarache which has seen its personnel reinforced, a new team started research work on materials, cells and processes within the CEA-LETI microelectronics laboratory based in Grenoble. In September 2002, ADEME and CEA decided to create a new research facility capable of developing new process technologies and new concepts on crystalline silicon cells up to 20 cm x 20 cm. The facility will become operational by the end of 2003.

The new ADEME's grid-connected distributed PV power system market stimulation initiative was founded on two favourable measures: a) new buy-back rates for photovoltaic electricity published by the Ministry of Industry and b) a subsidy up to 80 % of the investment would be brought in by ADEME, Regional Councils and other partners like the European Commission.

Two meetings gathering the stakeholders were organized in February and October 2002 by ADEME and the industry partners in order to present and discuss the technical, financial and legal conditions to implement the new BIPV programme. On this occasion ADEME and GENEC presented a compendium of best practices for installing grid-connected distributed PV power systems "*Guide de rédaction du cahier des charges techniques des générateurs photovoltaï ques connectés au réseau*". From his side CSTB (the French Construction industry scientific and technical centre) in partnership with ADEME has explained the first procedures for the technical assessment of the building integrated PV modules. The assessment campaign in view of issuing the Technical Approvals (ATec CSTB) will start in 2003.

A joint group including EDF and SER (a professional syndicate representative of the PV industry) developed both feed-in contracts and technical terms for grid connection of PV power systems. Nevertheless the precise terms of these contracts were not finalized by 2002 but officially released in 2003 after agreement of the French Energy Regulation Commission (CRE).

4.2 Indirect policy issues

Environmental treaties such as "The Framework Convention on Climatic Change" (1997) to favour the development and the promotion of renewable energy sources exerted to a certain extent an influence on the decision taken by the French Government to reactivate promotion of renewables. The 2006 general target of ADEME is to avoid the production of 1,3 Mt of carbon through the development of renewables. During the 1992-2002 period there were neither introduction of studies relating to externalities and hidden costs of conventional energy generation when compared to renewable energy nor environmental regulations which favoured the setting up of PV power systems over other conventional sources. Concerning the installation of PV systems in other countries than France, the GEF programme and its French equivalent FFEM did not contribute to any new rural electrification projects. Nevertheless it is worth noticing that ADEME with its institutional partners (Ministry of Foreign Affairs, IEPF, EDF, etc.) undertook several cooperation projects in targeted countries (Senegal, Vietnam, Mali, Haï ti, Burkina-Faso and Laos).

4.3 Standards and codes

Concerning qualification, the French standard "Norme Française" NF C57-100/103 for crystalline silicon PV modules (linked to an original quality insurance control procedure performed by an independent body) was replaced in 1997 by the international standard IEC 61215 of the International Electrotechnical Commission (IEC) issued in 1993. The equivalent standard IEC 61646 for thin film PV modules was also introduced to France. Note that the European Union certification ESTI/503 is based on the testing procedure of the IEC 61215 and Photowatt multicrystalline silicon PV modules refer to both of them. The storage batteries must refer to French standards NF C 58400 and/or to the recent NF C 58510 for PV accumulators. The switchboards and the conducting cables must refer to the French standards NF EN 60639 and NF C 32000.

ADEME and its partners such as EDF R&D division and CEA-GENEC collaborate to push the advancement of International Standards within the International Electrotechnical Commission (IEC/TC82). There is no French standard for balance of system components, except a description of PV pumping systems (NF C 3501).

The main technical specification for off-grid domestic PV system construction and operating is described in a handbook called « *Specifications for the use of renewable energies in rural decentralized electrification* ». The English version has become an IEC publicly available specification (IEC/PAS 62111). A joint coordination group gathering several IEC technical committees is reviewing the document: TC82 (photovoltaics), TC21 (storage batteries) and TC88 (wind energy). The Standard that will be issued will bear the number IEC TS 62257: *Recommendations for small renewable energy and hybrid systems for rural electrification*. Sections of the Standard will address the following topics: system selection; system design; technical specifications of generators, batteries and integrated systems; safety rules; acceptance, operation, maintenance and renewal and the last section being energy management. EDF and ADEME with their partners are strongly involved in the development of this International Standard.

In the case of domestic off-grid PV power systems there are no specific building code or land use limitation. Concerning building integrated systems, the French Organization for scientific and technical research in buildings (CSTB) carried out a study to set the professional rules and requirements similar to those of solar water heaters (waterproof, fire testing, etc.). When operational in 2003 ADEME and CSTB will partly fund the first certification tests of new products.

In 2002, GENECE and ADEME published a compendium of best practices for installing grid-connected distributed PV power systems “*Guide de rédaction du cahier des charges techniques des générateurs photovoltaïques connectés au réseau*”. Two types of systems are considered: systems directly connected to the grid and systems in which a means of storage is added in order to supply electricity in case of grid interruption of service (this concept will be used mainly in French overseas departments where cyclones or hurricane occur). The following items are addressed: electrical architecture, system sizing, protection against electrical hazards, fire and lightning, and earthing. The report ends with recommendations for building integration of PV modules. The guidebook containing recommendations on “*The protection of photovoltaic installations against lightning*” published by ADEME in 2001 was proposed in 2002 as a draft basis to the working group 3 (Task 3) of the International Energy Agency (IEA) photovoltaic power system programme. The guidebook should become, after review, a recommended practice book with an international scope.

ADEME with its partners is involved in the International Energy Agency photovoltaic power systems cooperation programme (IEA–PVPS: www.iea-pvps.org) and particularly within Task 1, Task 2, Task 3 (the French operating agent acts on behalf of ADEME and EDF) and Task 9. ADEME will join the new Task 10 in preparation. ADEME contributes also to the PV-GAP approval programme (www.pvgap.org). These bodies IEA and PV-GAP do not provide funds but participate to the dissemination of the PV technique and contribute to better quality products through the publication of technical documents and technical practical recommendations and specifications. Worth mentioning is the fact that the PV Company Photowatt international has been the first crystalline silicon module manufacturer to receive the label PV-GAP (beginning of 2003).

French technical experts are involved in the work of IEC (www.iec.ch) in the following Standards: IEC 61836 Ed.2: *Solar photovoltaic energy systems – terms and symbols*. IEC 62078: *Certification and accreditation programme for photovoltaic components and systems – guidelines for a total quality system*. IEC 62111: *General Directives for the use of REN in decentralized rural electrification*. IEC 62116: *Testing procedure – Islanding prevention measures for power conditioners used in grid-connected photovoltaic power generation systems*. IEC 62124: *Photovoltaic stand-alone systems – Design qualification and type approval*. IEC 62253: *Direct coupled photovoltaic pumping systems – Design qualification and type approval*. IEC 62257: *Recommendations for small renewable energy and hybrid systems for rural electrification – 10 parts*.

5 Highlights and prospects

Development of renewable source of energy in France gained some political interest in 1998. This was confirmed by an increase of the ADEME’s intervention budget in 1999, then confirmed in 2000, 2001 and 2002. The French Government expressed a new attitude towards energy management and renewable sources of energy and recognized that both concepts were matching well together for more efficient implementation. From 1999 to 2002, this policy allowed reinforcing the current strategy of developing and promoting quality products including systems and services for export purposes.

In 1999 a 4-year research and technological development programme on the various components of PV power systems and applications was deployed. Main topics include

innovative processing techniques to reduce production costs of components and increase their efficiency and reliability. Other topics include multi purpose d.c./a.c. inverters for off-grid and grid-connected applications, multi-function energy management devices for off-grid PV systems and multisource PV systems, lead-acid batteries adapted to rural electrification and other applications such as high performance and low-cost pumping devices, etc. Various studies were also being carried out: monitoring of off-grid rural electrification installations under the FACÉ fund, implementation of a PV system data bank (ISIS), monitoring of village power with hybrid system and micro-network, etc.

Concerning market stimulation initiatives, ADEME targeted the installation of 20 MW in 5 years of building integrated grid-connected distributed systems and 1,2 MW of rural electrification off-grid systems per year. New photovoltaic electricity buy-back rates were adopted in March 2002: 0,15 euros per kilowatt-hour in continental France, and 0,30 euros per kilowatt-hour in overseas departments and Corsica Region. For these types of projects ADEME, Regional Councils and/or the European Commission would bring up to 4,6 euros per watt as an investment subsidy. This new initiative became operational in 2002 nevertheless the feed-in contracts and the technical terms for grid connection of PV power systems would only receive the Energy Regulation Commission (CRE) agreement by mid 2003.

Annex A – Exchange rate, method and accuracy of data

A.1 Exchange Rate

The euro rate is 1 EUR = 6,559 57 FRF (2001). In 2002, the average exchange rate of euro is 1,00 EUR = 1,00 USD. Table A.1 gives the value in euro (2002) of 1 FRF in a given year.

Table A.1 – Value expressed in euros (2002) of one French franc from 1993 to 2002

1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
0,175 03	0,170 98	0,167 49	0,164 74	0,161 94	0,158 81	0,156 88	0,155 80	0,155 03	0,152 45
<i>1,148 11</i>	<i>1,121 55</i>	<i>1,098 66</i>	<i>1,080 62</i>	<i>1,062 25</i>	<i>1,041 72</i>	<i>1,029 05</i>	<i>1,021 97</i>	<i>1,016 92</i>	<i>1,000 00</i>

*The third line of Table A.1 gives the relative value (base 1 in 2001) of one euro in a given year.

A.2 Method and accuracy of data

The method used for gathering, processing and analysis the data was conducted by the author as follows.

A questionnaire was sent to the ADEME's partners participating to PV RTD programmes and market deployment programmes funded by ADEME, EDF, Regional Councils and the European Commission. The questionnaire written in French included at least the tables provided in the report.

The accuracy of the data is estimated to be $\pm 10\%$ for the installed PV capacity and 5% for the cell/module production of the companies that answered the ADEME questionnaire.

The installed capacities by small PV businesses (less than 5 persons) which have not answered the questionnaire or which were not approached are not included in the Tables.

Annex B – Definitions, symbols and abbreviations

For the purposes of the French national survey report, the following definitions, symbols and abbreviations apply.

B.1 Definitions

demonstration programme	Series of projects to demonstrate the operation of photovoltaic power systems and their application to potential users/owners.
field test programme	Series of projects to test the performance of PV power systems/components in real conditions.
final annual yield	Total photovoltaic energy delivered to the load during one year per kilowatt of PV array power installed. Unit: kWh per kW.
France	In this report by country France it is understood continental France, Corsica Island and French overseas Departments (<i>Guadeloupe, Guyane, Martinique and Réunion</i>) which are part of the European Union. Overseas Territories of New Caledonia (<i>Nouvelle-Calédonie</i>) and <i>Polynésie Française</i> are not considered.
grid-connected distributed photovoltaic power system	Power system installed on consumers' premises usually on the demand side of the electricity meter. This includes grid-connected domestic photovoltaic power systems and other grid-connected photovoltaic power systems on commercial buildings, motorway sound barriers, etc. These may be used for support of the utility distribution grid.
grid-connected centralized photovoltaic power system	Power production system performing the function of a centralized power station (also said centralized photovoltaic power plant).
installed power	Power delivered by a photovoltaic module or a photovoltaic array, under IEC Standard test conditions (STC): irradiance of 1 000 W/m ² , cell junction temperature of 25 °C, AM 1,5 solar spectrum). Also said STC output power. See also "peak power". Unit: W. (also written W_p , not encouraged).
market stimulation initiative	Activities to encourage the market deployment of PV through the use of market instruments such as green pricing, rate based incentives etc. They may be implemented by government, the finance industry, utilities, etc.
module manufacturer	A company carrying out the encapsulation of photovoltaic cells in the process of the production of photovoltaic modules.
Off-grid domestic photovoltaic power system	System installed in households and villages that are not connected to the utility grid. Usually, a means to store electricity is used (most commonly lead-acid battery). Also referred to as "stand-alone photovoltaic power system".
Off-grid non-domestic photovoltaic power system	System used for a variety of applications such as water pumping, remote communications, telecommunication relays, safety and protection devices, etc. which are not connected to the utility grid. Usually a means to store electricity is used. Also referred to as "stand-alone photovoltaic power system".
peak power	Amount of power produced by a PV module or PV array under IEC Standard test conditions (STC). Unit: W (also written W_p , not encouraged).
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 theoretically annual (monthly, daily) available energy per kilowatt of installed PV array power.
multicrystalline silicon (mc-Si) photovoltaic (PV)	Cast silicon, which has solidified at high rate with large grains. Pertaining to the direct conversion of light into electricity.
POLIX™	Trade name of multicrystalline Si directional solidification process and ingot/wafer from PV company Photowatt International.

polycrystalline silicon (pc-Si)	Thin layer of silicon (20 µm - 50 µm) deposited on a foreign substrate. Grain size: 1 µm to 1 mm.
photovoltaic array	A mechanically integrated assembly of photovoltaic modules and panels together with support structure to form a direct current (d.c.) power-producing unit.
photovoltaic cell	A basic photovoltaic device, which generates electricity when, exposed to a light such as the solar radiation.
photovoltaic module	The smallest complete environmentally protected assembly of interconnected photovoltaic cells.
photovoltaic panel	A group of photovoltaic modules fastened together, pre-assembled and wired, designed to serve as an installable unit in a photovoltaic array.
photovoltaic power system	Set of interconnected elements such as photovoltaic modules, inverters that convert d.c. Current of the modules into a.c. current, storage batteries and all installation and control components with a photovoltaic power capacity of 40 W or more. The typology is different according to application. See off-grid and grid-connected photovoltaic power systems.
PV power system market	Market for all nationally installed (terrestrial) PV applications with a PV capacity of 40 W or more.
Régions, Départements	Administrative units. In France a <i>Région</i> includes several <i>Départements</i>
stand-alone photovoltaic power system	Autonomous system with storage batteries (see off-grid photovoltaic power system).
standard test conditions (STC)	Testing conditions to measure photovoltaic cells or modules nominal output power. Irradiance level is 1 000 W/m ² , with the reference air mass 1,5 solar spectral irradiance distribution and cell or module junction temperature of 25 °C.
turnkey price	Price of an installed photovoltaic system excluding VAT/TVA/sales taxes, operation and maintenance costs but including installation costs. For an off-grid photovoltaic system, the prices associated with storage battery maintenance and replacement are excluded. If additional costs are incurred for reasons not directly related to the photovoltaic system, these are 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 are not included. Equally the additional transport costs of installing a telecommunication system in a remote area are not included).
wafer	Sheet of semiconductor material made by sawing it from a crystal ingot (thickness 150 µm to 300 µm).
wire saw	New type of saw used in PV industry to slice wafers as thin as 200 µm or less.

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B.2 Symbols and abbreviations

ADEME	Agence de l'environnement et de la maîtrise de l'énergie, French Agency for Environment and Energy Management. A public governmental organization.
AIE, IEA	Agence internationale de l'énergie (AIE). International Energy Agency (IEA).
a-Si, a-Si:H	Amorphous silicon material (thin film on glass substrate), hydrogenated alloy.
CEA	Commissariat à l'énergie atomique. French Atomic Energy Commissariat.
CEI, IEC	Commission Électrotechnique Internationale. International Electrotechnical Commission.
CNRS	Centre national de la recherche scientifique. French National Organization for Scientific Research.
DG RESEARCH	Directorate general for Research within the EC (formerly DG12)
DG TREN	Directorate general for Transport and energy within the EC (formerly DG17)
EC	European Commission of European Union.
EDF	Électricité de France (French electricity utility company).
EU, UE	European Union (15 countries). Union européenne (15 pays).
EUR	ISO currency code of European currency called euro. 1,0 EUR = 6,559 57 FRF (the euro replaces the French franc since January 2002).
FACÉ	Fonds d'amortissement des charges d'électrification rurale. Public rural electrification fund.
FRF	ISO currency code of French franc. 1,0 FRF = 0,152 45 EUR (fixed rate since 2002-01).
GEF	Global environment facility (World Bank).
IEA, AIE	International Energy Agency. Agence internationale de l'énergie.
IEA-PVPS	Photovoltaic power system cooperation programme of the IEA
IEC, CEI	International Electrotechnical Commission. Commission électrotechnique internationale.
ISO, ISO	International Organization for Standardization. Organisation internationale de normalisation.
PCRD	Framework programme of European Commission. RTD and demonstration.
MEUR	1×10^6 euros (one million euros).
MUSD	1×10^6 U.S. dollars (one million U.S. dollars).
mc-Si	Multicrystalline silicon material (ingot or wafer), moulded, grain size: 1 mm-10 cm.
μ, m, c, k, M, G	ISO Unit prefixes: $\mu = 10^{-6}$, $m = 10^{-3}$, $c = 10^{-2}$, $k = 10^3$, $M = 10^6$, $G = 10^9$.
NF	Norme française, French Standard.
OCDE	Organisation pour la Coopération et le Développement Économiques.
OECD,	Organization for Economic Cooperation and Development.
pc-Si	Polycrystalline silicon material deposited on a foreign substrate. Grain size 1 μm – 1 mm.
PV	Abbreviation for photovoltaic(s).
PVPS	Photovoltaic Power Systems. Name of an IEA cooperative programme.
RTD	Research, technological development (and demonstration).
RDT	Recherche et développement technologique.
sc-Si	Single crystal silicon material (ingot or wafer), CZ or FZ grown; grain size >10 cm.
STC	IEC Standard tests conditions: testing conditions to measure photovoltaic cells or modules output power. Irradiance level is 1 000 W/m ² , with the reference air mass 1,5 solar spectral irradiance distribution and cell or module junction temperature of 25 °C. IEC Standard.
USD	U.S.A. dollar (ISO currency code). 1,0 USD is roughly equivalent to 1 EUR.
W	Watt: SI unit of power. Symbol of watt is W. In this report it is understood PV array field power under standard test conditions (STC). Also written W_p (peak watt) by PV professionals to mean rated power at STC. Multiples like kW (10^3 W) or MW (10^6 W) are also used.
