Technology Collaboration Programme
by iea

International Energy Agency
Photovoltaic Power Systems Programme

Task 1 Strategic PV Analysis and Outreach

PVPS

National Survey Report of PV Power Applications in France

2021

ADEME
AGENCE DE LA TRANSITION ÉCOLOGIQUE

What is IEA PVPS TCP?

The International Energy Agency (IEA), founded in 1974, is an autonomous body within the framework of the Organization for Economic Cooperation and Development (OECD). The Technology Collaboration Programme (TCP) was created with a belief that the future of energy security and sustainability starts with global collaboration. The programme is made up of 6.000 experts across government, academia, and industry dedicated to advancing common research and the application of specific energy technologies.

The IEA Photovoltaic Power Systems Programme (IEA PVPS) is one of the TCP's within the IEA and was established in 1993. The mission of the programme is to "enhance the international collaborative efforts which facilitate the role of photovoltaic solar energy as a cornerstone in the transition to sustainable energy systems." In order to achieve this, the Programme's participants have undertaken a variety of joint research projects in PV power systems applications. The overall programme is headed by an Executive Committee, comprised of one delegate from each country or organisation member, which designates distinct 'Tasks,' that may be research projects or activity areas.

The IEA PVPS participating countries are Australia, Austria, Belgium, Canada, Chile, China, Denmark, Finland, France, Germany, Israel, Italy, Japan, Korea, Malaysia, Mexico, Morocco, the Netherlands, Norway, Portugal, South Africa, Spain, Sweden, Switzerland, Thailand, Turkey, and the United States of America. The European Commission, Solar Power Europe, the Smart Electric Power Alliance (SEPA), the Solar Energy Industries Association and the Cop- per Alliance are also members.

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What is IEA PVPS Task 1?

The objective of Task 1 of the IEA Photovoltaic Power Systems Programme is to promote and facilitate the exchange and dissemination of information on the technical, economic, environmental and social aspects of PV power systems. Task 1 activities support the broader PVPS objectives: to contribute to cost reduction of PV power applications, to increase awareness of the potential and value of PV power systems, to foster the removal of both technical and non-technical barriers and to enhance technology co-operation. An important deliverable of Task 1 is the annual "Trends in photovoltaic applications" report. In parallel, National Survey Reports are produced annually by each Task 1 participant. This document is the country National Survey Report for the year 2021. Information from this document will be used as input to the annual Trends in photovoltaic applications report.

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- **Data:** ENEDIS, SDES, RTE
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COVER PICTURE

36 kW on a municipal building by community solar group EnerCOA at Villefranche de Rouergue credit: EnerCOA

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ACKNOWLEDGEMENTS

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REFERENCES

The principal references are cited below; however, a number of additional sources, including web sites, private communications and diverse publications were also used.

- "Tableau de bord photovoltaïque", St@tinfo, n° 436, February 2022 (SDES — Service de la donnée et des études statistiques, Commissariat au Développement Durable, the Ministry for the Ecological and Inclusive Transition);
- Registre national des installations de production et de stockage d'électricité (National Register of Generators and electricity storage systems);
- "Bilans des Raccordements", Enedis Open Data (distribution grid manager for 95 % of the nation);
- "Bilan électrique 2021" (RTE Electricity Report 2021), RTE, February 2022 (Transport grid manager);
- "Baromètre annuel 2021", AVERE;
- « Coûts des énergies renouvelables et de récupération en France Edition 2022 » ADEME;
- "Charges de service public de l'énergie prévisionnelles au titre de l'année 2021", CRE;
- France Territoire Solaire Bilan T4 2021;
- "Baromètre 2021 du crowdfunding EnR", Green Univers;
- "Baromètre des achats d'énergie verte en France T4 2021 » Capgemini invent;
- "Le baromètre 2021 des énergies renouvelables électriques en France", Observ'ER;
- Public reports on national Call for Tenders dedicated to solar energy, CRE (Rapport de synthèse (version publique), Appel d'offres portant sur la réalisation et l'exploitation d'installations de production d'électricité à partir de techniques de conversion du rayonnement solaire, Commission de Régulation de l'Energie) (several publications, 2021 and 2022).

1 INSTALLATION DATA

The PV power systems market is defined as the market of all nationally installed (terrestrial) PV applications with a PV capacity of 40 W or more. A PV system consists of modules, inverters, batteries and all installation and control components for modules, inverters and batteries. Other applications such as small mobile devices are not considered in this report.

For the purposes of this report, PV installations are included in the 2021 statistics if the PV modules were installed and connected to the grid between 1 January and 31 December 2021, although commissioning may have taken place at a later date.

Data collection includes information on storage capacity, and injection type is now collected by Enedis (total or partial self-consumption, full generation sales).

Official statistics report the AC power of photovoltaic fields, despite eligibility for Feed-in Tariffs and Tender support mechanisms being indicated in by peak DC power thresholds. It may be useful for the reader to know that the average generation across France is 1 160 kWh/kW, but that systems installed in the southern half of mainland France and in overseas territories will generate more, up to 1 400 kWh/kW. For the purposes of this report, all AC data has been converted to DC power, with a standard ratio of 1.2 (AC to DC) unless otherwise specified. In the particular segment of utility scale systems, some data is available on both DC and AC power and the reported DC power has been used.

Little data is available on off-grid applications as there are few support mechanisms that allow observers to track installation volumes.

1.1 Applications for Photovoltaics

The principal applications for photovoltaics in France in 2021 are grid connected:

- Residential (house and multi-apartment) systems. These systems tend to range from one or two modules with self-consumption through to standard 3 kW, 6 kW or 9 kW systems. Much of the current total capacity was installed during the 2009 / 2011" boom" and is building integrated – however, since 2017, new capacity is only building applied PV;
- Commercial, agricultural or industrial systems on buildings (36 kW to 250 kW AC or around 300 kW DC). A small proportion (3% of total new capacity) are systems between 9 kW and 36 kW, generally on public buildings such as town halls, primary schools or technical services buildings;
- Industrial building mounted or parking canopy systems (250 kW to 10MW);
- Utility scale ground mounted systems (over 10 MW).

Small but growing segments include agrivoltaics and floating PV.

A small amount of off grid systems has been installed in overseas territories (Guiana, etc.) or in mainland mountainous areas.

Self-consumption has now become the norm for residential systems, with 95 % of newly commissioned systems (in cumulative power in the segment), compared to 70 % in 2018 for this segment.

There was strong growth across all segments, however large industrial and utility systems dominated once again, with 65% of installed power connected to the medium or high voltage grid, and residential systems accounting for less than 10% of installed volumes, despite a more

than doubling of quarterly volumes. Industrial and utility systems grew at a faster rate than other segments with installed capacity in these segments multiplied fourfold as compared to others where a doubling of capacity was witnessed.

1.2 Total photovoltaic power installed

With the combined increase in electricity consumption prices and costly grid connection costs for new distribution connection points, self-consumption models are growing across all segments. As such, the previous separation between centralised (no self-consumption) and decentralised (on buildings or with self-consumption) systems has become more difficult to define based only on systems power level. As such, the following segments, whilst informative, may be misleading as a growing capacity of self-consumption systems over 250 kVA are connected (50 MW reported in 2021, although current data collection practices are not adequate to quantify all systems with good accuracy).

Centralized: any PV installation which only injects electricity and is not associated with a consumer (no self-consumption) over 250 kW.

Decentralized: any PV installation which is embedded into a customer's premises (either with or without self-consumption) under 250 kW.

Cumulative PV installed capacity as of the end of 2021 reached 13 990 MW (AC — Alternative Current) or roughly 16,5 GW DC.

Data collection process

Data supplied by all transmission and distribution grid managers is aggregated and published by the SDES: Service de la Donnée et des Etudes Statistiques, Ministry for the Ecological and Inclusive Transition. Data is segmented by systems size (< 3 kW, < 9 kW, < 36 kW, < 100 kW, < 250 kW, above 250 kW). Data accuracy is an estimated 5%. Data publication segments published by the major distribution grid operator (DSO), Enedis, were modified and now include segments for total self-consumption, partial self-consumption and feed-in systems.

Capacity data published by the SDES and in the national register is given as the AC power of system, whilst Enedis does not specify if the data is DC or AC, but it does tend to correspond to AC power, with an unknown of the capacity of total self-consumption systems. If the difference between the DC and AC reported powers in the past was not consequent, the divergence is now increasing, particularly considering the current world-wide trend to reduce the AC/DC (inverter to modules) ratio. See introductory notes on the conversion actors.

For the purposes of this report, we have considered the following hypotheses for data collected in 2021:

Grid connected distributed (decentralized) systems:

- Residential: up to 9 kW - no data are available concerning the split BIPV/BAPV for new systems since 2017;
- Commercial: all systems 9 kW to 250 kW are Commercial BAPV (Building Applied Photovoltaics).

Grid connected centralised ground mounted systems:

- Industrial: all systems from 250 kW to 10 MW are Industrial or Ground-mounted. The split between Building-mounted and Ground-mounted is extrapolated from grid connection data published by Enedis;

- Utility scale systems: all systems over 10 MW and/or floating systems under 10 MW if known.

Off-grid PV power systems: There is no official data collection process for off-grid systems in France; any data presented are best-of-knowledge estimates.

Table 1: Annual PV power installed during calendar year 2021

		Installed PV capacity in 2021 [MW]	AC or DC
	Decentralized	1 133	DC
	Centralized	2 219	DC
	Off-grid	/	
	Total	3 350	DC

SOURCE: SDES, Observ'ER, Enedis, *estimated HESPUL

Table 2: PV power installed during calendar year 2021

			Installed PV capacity in 2021 [MW]	Installed PV capacity in 2021 [MW]	AC or DC
Grid-connected	BAPV	Residential	2 037	236	DC
		Commercial		896	DC
		Industrial		904	DC
	BIPV	Residential	No data available as feed-in tariff bonus for BIPV has been stopped	/	DC
		Commercial		/	DC
		Industrial		/	DC
	Utility-scale	Ground-mounted	1313	1 301*	DC
		Floating		12*	DC
		Agricultural		No data	DC
Off-grid		Residential	No data available		DC
		Other			DC
		Hybrid systems			DC
Total			3 350		DC

SOURCE: SDES, Enedis, industry press reports *estimated HESPUL; AC/DC conversion ratio for utility scale systems is 1.1 to reflect data from known utility scale systems commissioned in 2021.

Table 3: Data collection process

Conversion coefficient to estimate DC installations.	120%, unless otherwise stated. This is standard inverter dimensioning practice in mainland France.
Body collecting data	Data supplied by all transmission and distribution grid managers is aggregated and published by the Service de la donnée et des études statistiques, Commissariat au Développement Durable, the Ministry for the Ecological and Inclusive Transition in AC power. Enedis (national DSO) publishes segmented data. HESPUL has extrapolated and estimated data where these sources had no published data.
Link to official source	https://www.statistiques.developpement-durable.gouv.fr/les-energies-renouvelables?rubrique=21
Data quality	Data is provisional, and may be revised as grid operators provide additional information. Whilst standard inverter/PV field ratios exist, individual sites may differ, leading to uncertainty in the report DC volumes. Divergence in capacity volumes may exist; the error source may be related to reporting dates, provisional data and/or collection.

Table 4: The cumulative installed PV power in 4 sub-markets

Year	Off-grid [MW] (including large hybrids)	Grid-connected distributed [MW] (BAPV, BIPV)	Grid-connected centralized [MW] (Ground, floating, agricultural…)	Total [MW]
2008	22,9	180	8	211
2009	29,2	360	50	440
2010	29,3	1 126	290	1 445
2011	29,4	2 690	842	3 562
2012	29,6	3 662	1 214	4 906
2013	29,7	4 145	1 517	5 691
2014	29,75	4 756	2 051	6 836
2015	30,15	5 108	2 782	7 920
2016	30,15*	5 488	3 118	8 635
2017	30,15*	5 982	3 701	9 713
2018	30,15*	6 410	4 315	10 756
2019	30,15*	6 955	4 945	11 931
2020	30,15*	7 571	5 497	13 098
2021	30,15*	8 704	7 716	16 450

SOURCE: SDES and previous IEA NSR-FR reports (revised), PV Atlas Observ'ER and ADEME. NOTE: The capacity published here differs to those published in previous reports as a result of the conversion from AC to DC power. * No data available

Table 5: Other PV market information

<table>
<tr><td></td><td>2021</td></tr>
<tr><td>Number of PV systems in operation in your country</td><td>
<table>
<tr><th>Peak Power range</th><th>Installations (number)</th><th>Power [MW DC]</th></tr>
<tr><td>0 – 3 kW</td><td>376 090</td><td>1 200</td></tr>
<tr><td>3 kW–9 kW</td><td>129 677</td><td>950</td></tr>
<tr><td>9 kW–36 kW</td><td>24 946</td><td>730</td></tr>
<tr><td>36 kW–100 kW</td><td>27 330</td><td>2 780</td></tr>
<tr><td>100 kW–250 kW</td><td>8 505</td><td>1 875</td></tr>
<tr><td>> 250 kW</td><td>2 475</td><td>8 915</td></tr>
<tr><td>Total</td><td>569 023</td><td>16 450</td></tr>
<tr><td>Total Off-grid</td><td></td><td>30</td></tr>
</table>
</td></tr>
<tr><td>Capacity of decommissioned PV systems during the year [MW]</td><td>0 (estimated).</td></tr>
<tr><td>Capacity of repowered PV systems during the year [MW]</td><td>0 to 10 (estimated).</td></tr>
<tr><td>Total capacity connected to the low voltage distribution grid [MW]</td><td>566 548 systems for 7 535 MW.</td></tr>
<tr><td>Total capacity connected to the medium voltage distribution grid [MW]</td><td>2 386* systems for 7 700 MW DC (6 420 MW DC).</td></tr>
<tr><td>Total capacity connected to the high voltage transmission grid [MW]</td><td>89 systems for 969 MW DC (807 MW AC).</td></tr>
<tr><td>Unregistered capacity</td><td>Analysis of the data from the 3 major sources (SDES, Enedis and the Register) indicates a missing capacity of approximately 500 MW AC in the Register, for systems connected to the medium and high voltage grid. As such, whilst total capacity would seem to be around 16,45 GW, the error margin is plus 0,5 GW/ minus 1 GW.</td></tr>
</table>

Sources: SDES, Registre national des installations de production et de stockage d'électricité (2021), Open data réseaux énergies (ODRÉ) *Hespul extrapolations. Data has been converted from reported AC to DC power, with a standard ratio of 1,2 (1,15 for systems over > 250 kW), and rounded.

Table 6: PV power and the broader national energy market

	Data	Year
Total power generation capacities [GW]	Total: 139,07 GW of which • Nuclear: 61,37 GW; • Fossil fuel: 17,9 GW; RES: 59,8 GW (see below)	2021
Total renewable power generation capacities (including hydropower) [GW]	• PV*: 13,1 GW; • Hydro: 25,7 GW; • Wind: 18,8 GW; • Other RES: 2,2 GW	2021
Total electricity demand [TWh]	468 TWh	2021
New power generation capacities installed [GW]	Total: 2,7 GW of which • Gas: +0,496 GW; • Coal: - 1,16 GW; • Diesel: 0,0 GW; • Nuclear: 0 GW; PV and other RES: 3,9 GW (see below)	2021
New renewable power generation capacities (including hydropower) [GW]	• PV*: + 2,69 GW; • Wind: + 1,19 GW; • Hydro: + 0,00 GW; • Other RES: + 0,06 GW	2021
Estimated total PV electricity production (including self-consumed PV electricity) in [TWh]	PV: 14,809 TWh	2021
Total PV electricity production as a % of total electricity consumption	3 %	2021
Average PV yield in [kWh/kW]	1 160 kWh/kW (30° with system losses (PV GIS) – France mainland) Ranges from 900 kWh/kW to 1 550 kWh/kW (30° with system losses (PV GIS) – continental France)	2021

2021: RTE France Electricity Report 2021. *Data in this table is provided by RTE and provisional PV ***are AC power only***.

** Source: SDES, non-energy uses included.

1.3 Key enablers of PV development

Table 7: Information on key enablers

	Description	Annual Volume (Number of units)	Total Volume	Source
Decentralized storage systems	Systems connected to the low voltage distribution grid. Does not include data for overseas territories' or systems connected to the medium voltage grid	6,66 MW for 830 systems on mainland	31,8 MW for 8 357 systems	Enedis Open Data, EDF SEI
Residential Heat Pumps	Mono and multi-split reversible heat pumps	837 629	5 895 864	www.uniclima.fr Uniclima: Bilan 2021 et perspectives 2022 du génie climatique
	Thermodynamic domestic water heater	150 615	868 386	
Electric cars	Cars & Lightweight utility vehicles	174 191	512 178	www.avere-france.org AVERE: Bilan 2021 Mobilité éléctrique
	Hybrid rechargeable cars	141 787	274 096	
	Public charge points	20 931	53 667	www.avere-france.org AVERE: Bilan 2021 Infrastructures de recharge ouvertes au public

2 COMPETITIVENESS OF PV ELECTRICITY

The past year was unprecedented for the competitiveness of photovoltaic electricity in France, as in much of Europe. Rising equipment costs due to follow on effects of COVID and economic growth (primary materials costs, supply chain disruptions, local and international growth markets) increased the cost of photovoltaic systems, with significant impacts on module and steel costs, amongst others. On the other hand, through 2021 market costs of electricity ballooned as gas prices rose on the back of strong economic growth and demand, leaving photovoltaic as an increasingly attractive source of electricity despite its concurrent, but lower, increased costs.

Data on market prices is published irregularly, based on either surveys or, when published by the Energy Regulation Commission, data provided by tender candidates. 2021 data are based on limited market surveys conducted for the purposes of this report, and due to the different factors disrupting the market, can only be used as a guide, with significant cost differences between early and late 2021, and even greater differences between prices quoted in 2021 for future systems, and prices paid in 2021 for systems reaching commissioning. Given the continued market tension in 2022, an indication of indicative costs can only be representative of a short time period, well under a year – as such the level of uncertainty on the indicated costs is high.

2.1 Module prices

A 2019 study by the Energy Regulation Commission (CRE) provides the most recent large-scale survey of price breakdowns in France. The business plans in the CRE study include the module prices that the candidates expect to pay. The lead-time between project submission to the tender and module acquisition is generally between 16 and 18 months. Module costs reported below are average costs according to the expected commissioning year, and are differentiated according to the system size. This survey is still used as the basis for cost estimations and market reports by public and private organisations in France (including ADEME).

Table 8: Typical module prices (€/Wp) for a number of years

Year	2016	2017	2018	2019	**Typical price of a standard module crystalline silicon** 2020	**Typical price of a standard module crystalline silicon** 2021
Average module price (all technologies) for systems in Tenders	0,7	/	/		0,35-0,4*	0,25 – 0,4
Average module price (all technologies) for systems in Building Applications PV Tenders Over 90 % of modules in the survey were monocrystalline silicon		0,6	0,6	0,45		
Average module price (all technologies) for systems in ground based PV Tenders 60 % of modules in the survey were monocrystalline silicon, 13 % polycrystalline silicon and 27 % thin film technologies		0,55	0,4	0,4		

SOURCE: CRE “Coûts et rentabilités du grand photovoltaïque en métropole continentale”, pvXchange and Hespul estimate. 2021 data from Hespul limited market survey.

2.2 System prices

There is a wide range in turnkey prices, especially in the small to medium size segment. This range of prices is determined by the ease of installation (or the state of repair and complexity of the existing roof), the type of supporting structures needed, the complexity of the grid connection and the development time associated with these complexities. Through 2021, those companies working on residential and small scale systems generally maintained costs with small negative to small positive changes.

Table 9: Turnkey PV system prices of different typical PV systems

Category/Size	Typical applications and brief details	Current prices [€/W]
Residential BAPV < 3 kW	Grid-connected, roof-mounted, distributed PV systems installed to produce electricity to grid-connected households. Typically roof-mounted systems on villas and single-family homes. Equipment and labour.	2,3 – 2,5
Residential BAPV 5-10 kW	Grid-connected, roof-mounted, distributed PV systems installed to produce electricity to grid-connected households. Typically roof-mounted systems on villas and single-family homes. Equipment and labour.	1,7 – 2,5
Residential BIPV 5-10 kW	Grid-connected, building integrated, distributed PV systems installed to produce electricity to grid-connected households. Typically, on villas and single-family homes. Equipment and labour.	2,0 – 3,5
Small commercial BAPV 10-100 kW	Grid-connected, roof-mounted, distributed PV systems installed to produce electricity to grid-connected commercial buildings, such as public buildings, multi-family houses, agriculture barns, grocery stores etc. Equipment and labour. Grid connection not included.	0,6 - 1,7
Large commercial BAPV 100-250 kW	Grid-connected, roof-mounted, distributed PV systems installed to produce electricity to grid-connected large commercial buildings, such as public buildings, multi-family houses, agriculture barns, grocery stores etc. Grid connection not included.	0,7 - 1,1
Industrial BAPV >250 kW	Grid-connected, roof-mounted, distributed PV systems installed to produce electricity to grid-connected industrial buildings, warehouses, etc. Grid connection not included.	0,8 - 1,1
Small centralized PV 1-10 MW	Grid-connected, ground-mounted, centralized PV systems that work as central power station. The electricity generated in this type of facility is not tied to a specific customer and the purpose is to produce electricity for sale. With few exceptions, financed through competitive tender.	0,5 - 0,9
Medium centralized PV 10-20 MW	Grid-connected, ground-mounted, centralized PV systems that work as central power station. The electricity generated in this type of facility is not tied to a specific customer and the purpose is to produce electricity for sale. With few exceptions, financed through competitive tender.	0,5 - 0,9
Parking canopies 5 to 10 MW	Grid-connected, distributed PV systems installed over impermeable car parks to produce electricity to grid-connected industrial buildings, warehouses, etc. Financed through competitive tender.	0,9 – 1,1
Floating centralised PV	Financed through competitive tender.	1

SOURCE: FiT systems: estimation HESPUL from sources Hespul. Tenders source: CRE “Coûts et rentabilités du grand photovoltaïque en métropole continentale”, Etude ADEME “Coûts des énergies renouvelables et de récupération en France”, HESPUL estimations.

Table 10: National trends in system prices for different applications

Year	Residential BAPV Grid-connected, roof-mounted, distributed PV system 5-10 kW **[euro/W]**	Small commercial BAPV Grid-connected, roof-mounted, distributed PV systems 10-100 kW **[euro/W]**	Large commercial BAPV Grid-connected, roof-mounted, distributed PV systems 100-250 kW **[euro/W]**	Centralized PV Grid-connected, ground-mounted, centralized PV systems 10-50 MW **[euro/W]**
2007	8,4	7,8		6,3
2008	8,2	7,6		6,2
2009	6,9	6,4		5,2
2010	5,9	5,5		4,5
2011	3,9	2,6		2
2012	3,7	2		1,6
2013	2,7	2		1,3
2014	2,6	2		1,3
2015	2,5	1,9		1,2
2016	2,41	1,58		1,1
2017	2,2	1,2		0,9 - 1,1
2018	2,2	1,2		0,7 - 0,9
2019	2	1,2	1,2	0,65 – 0,85
2020	1,9	1,1	0,9	0,65 – 0,85
2021	1,7 – 2,5	0,6 – 1,7	0,7 – 1,1	0,5 – 0,9

NOTE — The table includes BIPV-IAB systems up to 3 kW until 2012, BIPV-IAB systems up to 9 kW from 2013 to 2016 and BAPV systems up to 9 kW since 2017.

SOURCE: Previous IEA NSR-FR reports, limited market surveys by Hespul, VAT not included. *IAB: completely building integrated; **ISB: simplified building integration; BAPV building applied / roof top systems.

2.3 Cost breakdown of PV installations

The Renewable Energy Trade Association (Syndicat des Energies Renouvelables, SER) study evaluating the contribution to renewable to the French economy, published in 2020, builds on the 2019 energy Regulation Commissions study on the cost of photovoltaics in France, with results as detailed below. This data is still used in national studies by private and public bodies as they are the most recent, comprehensive, publicly available studies. Limited market surveys have been used to evaluate the cost redistributions in the context of rising upstream costs as professionals responded to these events.

Table 11: Cost breakdown for a grid-connected roof-mounted, distributed residential PV system of 5 to 10 kW

Cost category	Average [€/W]
Hardware	
Module	0,57
Inverter	0,27
Mounting material	0,32
Other electronics (cables, etc.), including installation	0,33
Subtotal Hardware	1,49
Soft costs	
Installation work	(included in Other Hardware costs)
Planning	0,1
Shipping and travel expenses to customer	
Customer acquisition	
Permits and commissioning (i.e. cost for electrician, etc.)	
Project margin	
Subtotal Soft costs	0,1
Grid connection	0
Total (excluding VAT)	**1,59**
Average VAT	20%

SOURCE: “Évaluation et analyse de la contribution des énergies renouvelables à l’économie de la France et de ses territoires” SER/EY June 2021 + market surveys (Hespul).

For this segment, module and inverter prices are well above that of other segments; in France both distributors and installers add a margin to module costs.

Table 12: Cost breakdown for a grid-connected, ground-mounted, centralized PV systems of > 10 MW

Cost category	Average [€/W]
Hardware	
Module	0,25
Inverter	0,06
Mounting material	0,16
Other electronics (cables, etc.), including installation	0,17
Subtotal Hardware	**0,64**
Soft costs	
Installation work	(included in Other Hardware costs)
Planning	0,13
Shipping and travel expenses to customer	
Customer acquisition	
Permits and commissioning (i.e. cost for electrician, etc.)	
Project margin	
Subtotal Soft costs	**0,13**
Grid connection	0,08
Total (excluding VAT)	**0,85**
Average VAT	20%

SOURCE: “Évaluation et analyse de la contribution des énergies renouvelables à l’économie de la France et de ses territoires” SER/EY June 2021, Estimations by HESPUL

2.4 Financial Parameters and specific financing programs

Table 13: PV financing information in 2021

Different market segments	Loan rate [%]
Average rate of loans – residential installations	4% - 7% over 12 years, slight reduction compared to 2020*
Average rate of loans – commercial installations	From 1,1% to 1,5% for 12 to 18 years
Average cost of capital – industrial and ground-mounted installations	3% over 20 years**

SOURCE: ADEME study "Coûts des énergies renouvelables et de récupération en France" 2022, CRE "Coûts et rentabilités du grand photovoltaïque en métropole continentale", Statinfo Crédit à la Conso and Crédit au SNF, Taux des crédits aux entreprises by Banque de France, estimation Hespul.

* Rate of loans for residential applications are considered consumer credit which explains their relatively high level, well above home loans.

** The ADEME study considers an average cost of capital for 2020 at 3,2% for 80% debt financing, and 3,6% for 70% debt financing, with a relative stability from 2019 to 2020; for the purposes of this report values from market surveys were included leading to slightly lower values.

Interest rates for all sectors remained low and decreasing through 2021, albeit with slight rises in December for residentials.

2.5 Specific investments programs

Table 14: Summary of existing investment schemes

Investment Schemes	Introduced in France
Third party ownership (no investment)	Used for commercial and industrial systems (roof and land rental), but also to a lesser extent on new agricultural buildings.
Renting	A few small-scale operations in self-consumption models where building occupiers rent PV systems. This is a growth segment with high interest in 2021 as electricity prices rose.
Leasing	Leasing is a common financing instrument in France for commercial systems. "Sofergie" (Energy Financing Company) provide credit or leasing options for projects developed by municipalities, social housing organisations, commercial companies and agricultural companies.
Financing through utilities	Some electric utilities (more often their subsidiaries) develop and invest in PV systems, but they do not offer finance for third parties. Utilities can access all support mechanisms, including FiT and Tenders for systems that they develop or own.

Investment in PV plants against free electricity	(See self-consumption).
Crowd funding (investment in PV plants)	Crowd-funding generally finances debt through crowd-funding platforms, however some platforms allow for equity financing. Changes to the bonus mechanisms in the new PPE2 Tenders have resulted in a significant shift from citizen investment and governance to debt crowdfunding.
Community solar	Yes
International organization financing	No

The main financing organizations are commercial banks (both French and foreign), debt funds (French and foreign insurers) and institutional lenders (European and national).

Cleantech investments in France grew again in 2021, and whilst the RES sector was overtaken by the circular economy sector, growth in the RES sector was spectacular with a doubling of investments to nearly 600 million (not including hydrogen). The largest operation in the RES sector was Neon, with 255 million euro raised with cleantech funds (for a total of 600 million in the operation) towards its investment 2021-2025 program.

Portfolio financing

Portfolio financing/refinancing and large or utility-scale projects can make use of the European Investment Bank (European long-term investment fund—EIB) offers.

The EIB supports a number of renewable energy source (RES) investments funds available for photovoltaics projects. The EIB approved a number of credit lines to local financing organisation within different mechanism including the Private Finance for Energy Efficiency (PF4EE) collateral agreement, the CALEF - PAN-EUROPEAN RENEWABLE ENERGY FL and SAAR LB CLIMATE ACTION MBIL II loans (respectively 200 million euros and 150 million euros for small to medium projects).

Other major actors include La Banque des Territoires (Caisse des Dépôts) and its subsidiary Bpifrance.

Project financing

Project financing, classically used for infrastructure projects, is based on project cash flows repaying project debt and equity. Project financing for privately owned projects is available through both commercial banks and bpifrance, a public investment bank. Public authorities can access financing from public long-term investors such as the Caisse des Dépôts (Deposits and Consignments Fund).

Project financing is also available through Sofergies - financial institutions that provide debt financing or leasing options for energy efficiency and renewable energy projects by

municipalities, social housing organisation, commercial companies and agricultural companies.

Bpifrance has increased volumes available for project financing as part of its 2021-2024, building on its regional presence to identify local requirements.

Community solar (citizen investment)

Citizen investment is mobilised through specific citizen RES funds and crowdfunding platforms—financing both equity and debt. The principal organisations active in channelling citizen investment are crowdfunding platforms (debt and equity investments) and Energie Partagée. Energy Partagée collected 2,2 million euros in 2021.

30 new solar community projects for 22,6 MW were commissioned in 2021, bringing the total since inception up to 76 MW, representing 15 million euros in direct community investment for systems ranging from small 9 kW projects to multi-MW ground-based systems.

Crowdfunding

Crowdfunding projects once again increased in volume in 2021, with, for the first time, more crowdfunding equity than debt for renewable energy projects within the framework of the competitive Tenders.

Financing of photovoltaics through crowdfunding:

- Roof-mounted systems: 33 million euros raised for 258 MW across 151 projects;
- Ground-based systems: 68 million euros raised for 1 344 MW across 151 projects;
- Floating systems: 1 million euros raised for 30 MW across 3 projects.

Residential project financing

Residential systems are financed through different schemes: 100% owner capital, home renovation loans or consumer credit loans.

2.6 Additional Country information

Table 15: Country information

Retail electricity prices for a household	Time of use contracts available. Eurostat Band DC (2 500 kWh < consumption < 5 000 kWh) • 202,2 €/MWh all taxes and levies included.
Retail electricity prices for a commercial company	Time of use contracts available. Eurostat Band IB (20 MWh < consumption < 500 MWh): • 130 €/MWh excluding VAT and other recoverable taxes and levies: • 154 €/MWh all taxes and levies included. Eurostat Band IC (500 MWh < consumption < 2 000 MWh): 100 €/MWh excluding VAT and other recoverable taxes and levies: • 120,7 €/MWh all taxes and levies included.
Retail electricity prices for an industrial company	Time of use, demand response, peak shaving contracts available. Eurostat Band ID (2 000 MWh < consumption < 20 000 MWh): • 88,2 €/MWh excluding VAT and other recoverable taxes and levies; • 104,7 €/MWh all taxes and levies included.
Liberalization of the electricity sector	France's electricity industry is highly concentrated but not vertically integrated in theory. However, in practice, EDF, (the state holds over 80% of EDF share capital) and its different wholly or partially owned subsidiary companies are the principal generator (over 80% of electricity production), transport grid manager (100%), distribution grid manager (over 95% of grid subscribers) and retailer (over 75% of retail customers).

SOURCE: INSEE, CRE, Eurostat [nrg_pc_204] and (nrg_pc_205) 2021S2.

3 POLICY FRAMEWORK

This chapter describes the support policies aiming directly or indirectly to drive the development of PV. Direct support policies have a direct influence on PV development by incentivizing or simplifying or defining adequate policies. Indirect support policies change the regulatory environment in a way that can push PV development.

Table 16: Summary of PV support measures

Category	Residential		Commercial + Industrial		Centralized	
Measures in 2021	**On-going**	**New**	**On-going**	**New**	**On-going**	**New**
Feed-in tariffs	Yes	Yes (changes to Feed in Tariff conditions)	Yes, (competitive Tenders)	Yes (Open access Feed in Tariffs up to 500 kW)	-	-
Feed-in premium (above market price)	-	-	Yes, (competitive Tenders)		Yes, (competitive Tenders)	
Capital subsidies	-	-	Yes, some regions. Terminated in 2021	-	-	-
Green certificates	-	-	-	-	-	-
Renewable portfolio standards (RPS)	-	-	-	-	-	-
Income tax credits	-	-	-	-	-	-
Self-consumption	Yes	-	Yes	-	-	-
Net-metering	-	-	-		-	-
Net-billing	Yes	Yes (Changes to Feed in Tariff conditions)	Yes	Yes (Feed in Tariffs up to 500 kW)	-	-

Collective self-consumption and virtual net-metering	Yes	-	Yes	-	-	-
Sustainable building requirements	Yes	-	Yes	Yes (changes to conditions for mandatory solar/living roofs, threshold lowered to 500 m^2 and new types of buildings under obligation)	-	-
BIPV incentives	-	Yes (cumulative with Feed in Tariffs)	-	Yes (cumulative with Feed in Tariffs for up to 500 kW)	-	-

3.1 National targets for PV

The framework for developing photovoltaics policies in France falls within the long term National Low Carbon Strategy (SNBC, 2050 horizon) and the 10-year Energy Programme Decree (PPE). The current PPE, published in 2020, targets 3 GW to 5 GW a year new capacity, to reach 20 GW in 2023 and 35 GW to 44 GW in 2028. The PPE authorizes competitive tenders as the preferred mechanism to reach these goals if market forces are insufficient.

The government has signalled a real desire to meet the PPE targets, publishing an Action Plan to accelerate the development of photovoltaics in November. This plan includes a possible feed in tariff for ground-based systems under 500 kW on wasteland, 1 000 projects on public land and buildings, a reduction in upfront grid connection costs and simplifications to administrative procedures.

The national environmental agency, ADEME, the national Transport network operator and an independent organisation négaWatt all published possible future energy scenarios in 2050, and all scenarios had a common element of high photovoltaics volumes needed in France by 2050, with volume ranging from 90 GW to nearly 200 GW – an indication of the accepted level of investment required from both the public and private sectors.

3.2 Direct support policies for PV installations

The measures summarized in table 16, and their effectiveness, are described below.

Support measures include, for individual self-consumed electricity from systems under 1 MW, exemption from the tax surcharges, local electricity and grid taxes and VAT (these taxes and levies normally represent approximately 30% of a consumer's electricity bill). Property tax exemptions for agricultural and public-sector buildings equipped with photovoltaic systems are also in place, and thermal and environmental building regulations that should encourage the use of photovoltaics on new buildings.

3.2.1 Open volume feed-in tariffs for BAPV

Feed-in tariffs and net-billing tariffs are segmented according to system size and decrease each trimester, with the decrease pegged to grid connection requests for previous trimesters. For overseas regions, the tariffs are adapted to regional irradiation levels. Tables 17 and 18 detail 4th quarter 2021 tariff levels.

A new framework from October 2021 for feed in tariffs for systems up to 500 kW (up from 100 kW) on buildings, greenhouses and parking canopies on mainland France includes differentiated tariffs depending on system size, and lump sums for smaller self-consumption systems (with net-billing) as well as specific building integrated products. Systems may now participate in collective self-consumption projects, and changes have improved access to tariffs for systems on publicly owned buildings. Mandatory 550 kg CO_2/kW maximum carbon footprint for modules in systems between 100 kW and 500 kW.

Table 17 — Feed-in Tariff and Tender remuneration levels –Mainland France

Tariff category	Power of PV installation	Tariff Q4 2021* (EUR/MWh)
Continental France — building applied PV		
Ta (no self-consumption)	≤3 kW	178,9
Ta (no self-consumption)	3 kW to 9 kW	152,1
Tb (no self-consumption)	9 kW to 36 kW	108,9
Tb (no self-consumption)	36 kW to 100 kW	94,7
Tc (with or without self - consumption)	100 kW to 500 kW	98,0

* For projects that will be built in 2022 or first semester 2023.

Table 18: Feed-in Tariff and Tender remuneration levels–Overseas France

Tariff category	Power of PV installation	Tariff Q4 2021 (EUR/MWh)
Tariff base		8,12
Sample system in Guadeloupe	2 kW	186,5
Sample system in Corsica	8 kW	146,3
Sample system in Réunion	50 kW	130,0
Power factor		
≤3 kW 3 kW to 9 kW 9 kW to 36 kW 36 kW to 100 kW	1,35 1,2 1,1 1 0	= 8,12 x 1,35 x location factor = 8,12 x 1,2 x location factor = 8,12 x 1,1 x location factor = 8,12 x 1x location factor = 0
Location factor		
Guadeloupe & Martinique Corsica Réunion French Guiana Mayotte	17 15 16 18 19	= 8,12 x 17 x power factor = 8,12 x 15 x power factor = 8,12 x 16 x power factor = 8,12 x 18 x power factor = 8,12 x 19 x power factor

Note: To calculate overseas tariffs, multiply the trimestral tariff base by the power factor and a location factor—for exact tariffs, refer to CRE publications.

Note: there is also a time-based compensation for grid manager commanded disconnections.

3.2.2 Feed-in tariffs and Feed-in premiums in competitive tenders

Volume capped periodic competitive tenders for systems from 500 kW to 30 MW (no size limit for ground-based systems on waste land) are segmented according to size and application (building applications, ground based etc.).

Eight competitive tenders were held in 2021 in mainland France, whilst the target volume was over 2,3 GW, only 2,02 GW of projects were awarded: 656 MW for building applied, 1,34 GW for ground-based systems, and 25 MW self-consumption systems.

3.2.3 BIPV development measures

The new feed in tariff framework published in October 2021 included an investment bonus for systems up to 500 kW using one of 4 approved, certified BIPV products. To be paid in 5 yearly instalments, the investment bonus is available for a maximum of 145 MW of projects over 2 years (30 MW in 2022, 115 MW in 2023) on a first come first served basis. The bonus can by combined with the partial self-consumption bonus and feed in tariffs/net billing.

Table 19 — Feed-in Tariff BIPV bonus – Mainland France

System size	Bonus for grid connection request in the first period from 09/10/2021 au 08/10/2022, capped at 30 MW	Bonus for grid connection request in the second period from 09/10/2022 au 08/10/2023, capped at 115 MW
< 100 kW	0,238 EUR per W installed	0,133 EUR per W installed
100 kW to 250 kW	0,235 EUR per W installed	0,128 EUR per W installed
250 kW to 500kW	0,233 EUR per W installed	0,125 EUR per W installed

A number of indirect measures included reducing the threshold for mandatory solar or living roofs for commercial and industrial buildings or covered car parks to those occupying 500 m^2 of ground surface (down from 1 000 m^2) and including new types of buildings.

Actual thermal regulations, and incentive high-performance building labels encourage photovoltaics and self-consumption as electricity consumed and exported from the building can be integrated in building performance calculations. In particular, the “Bâtiments à Energie Positive et Réduction Carbone (E+/C-)” label currently prefigures future building thermal regulation that will come into force in 2022. The future regulation includes a new set of criteria on energy and carbon, also applied to photovoltaics equipment.

3.3 Self-consumption measures

Table 20: Summary of self-consumption regulations for small private PV systems in 2021

PV self-consumption	1	Right to self-consume	Individual self-consumption: the PV generator can be the consumer or a third-party owner. Participation in a collective self-consumption operation is limited to 3 use cases (see below): Virtual net-metering (virtual battery storage): the consumer must be the PV generator.
	2	Revenues from self-consumed PV	Lump-sum for partial self-consumption systems in association with net-billing FiT. Winning candidates in the Self-Consumption Tender (systems from 500 kW to 10 MW) will receive a bonus on self-consumption at the tendered rate. Self-consumed electricity is not subject to tax for individual self-consumption. However, collective self-consumption is subject to tax. For individual self-consumption and in case of partial self-consumption, installed capacity is subject to capacity taxes, such as grid taxes.

	3	Charges to finance Transmission, Distribution grids & Renewable Levies	Systems with total self-consumption pay no connection or annual grid access costs. Systems in collective self-consumption systems pay grid connection costs and annual access fees.
Excess PV electricity	4	Revenues from excess PV electricity injected into the grid	Net-billing set by FiT (6, 9,8 or 10 c€/kWh depending on system size), or by Tender specifications (FiT or wholesale market + premium) or by PPA (Power Purchase Agreement). This does not apply to collective self-consumption.
	5	Maximum timeframe for compensation of fluxes	30 minutes.
	6	Geographical compensation (virtual self-consumption or metering)	Called “collective self-consumption” in France. Participation in a collective self-consumption operation is limited to 3 use cases: • ***Default case:*** PV installations and consumers located in the same building. This opens the possibility for the participation of medium voltage connected PV installations; • ***Extended case***: PV installations and consumers connected to the low voltage grid within a distance of 2 km of each other; • ***Exceptional case:*** PV installations and consumers within a distance of 20 km, where the low population and building density requires an exceptionally large perimeter; • In all case, generators(s) and consumers(s) must be linked through a common legal entity. Compensation on a 30 minute time-step.
Other characteristics	7	Regulatory scheme duration	20 years for surplus (net-billing) sold in FiT, 10 years in Self-Consumption Tender.
	8	Third party ownership accepted	Third party ownership is allowed.
	9	Grid codes and/or additional	Grid connection fees for systems over 36 kVA.

		taxes/fees impacting the revenues of the prosumer	No grid access fees for total self-consumption systems. Reduced grid access fees for partial self-consumption systems (with net-billing). Energy taxes will apply in the case of collective self-consumption but not for individual self-consumption, even if the PV system is owned by a third-party.
	10	Regulations on enablers of self-consumption (storage, DSM…)	Electricity storage is considered as both a consumer and a generator when integrated into collective self-consumption.
	11	PV system size limitations	Automatic grid connection limited to systems < 36 kVA with no surplus injections and no grid fees– other systems require approval. Systems size limited on buildings for access to net-billing (500 kW) and lump-sum (100 kW) within FiT framework. Systems must be between 500 kW to 10 MW to be eligible for the new 2021-2026 competitive tenders. In the case of "extended" collective self-consumption projects, the total PV volume is limited to 3 MW mainland and to 0,5 MW (power is expressed in peak DC power) in non-interconnected territories.
	12	Electricity system limitations	Mainland, no limits. In overseas territories (ZNI), self-consumption systems must respect the same capacity and disconnect limits as feed-in systems (i.e. active capacity must not go over 30% (or as specified in the regional energy planning decree) of consumption (with the objective of raising this threshold to 45% by 2023), grid manager disconnects on a first installed-last disconnected priority order).
	13	Additional features	Markets sales of surplus in the framework of Tenders require access to an Aggregator/Balancing Responsible Party. Collective self-consumption systems may now access FiT for excess production sales (changed in October 2021). Several virtual battery storage offers are available.

3.3.1 Net-billing feed-in tariff and lump sum for BAPV systems under 100 kW

Table 21: Net billing Feed-in Tariffs for BAPV systems

Tariff category	Power of PV installation	Net-billing tariff (+ lump sum) Q4 2021 (EUR/MWh)
Continental France — building applied PV		
Pa (net-billing)	≤3 kW	100 (+0,38 EUR/W installed)
Pa (net-billing)	3 kW to 9 kW	100 (+ 0,29 EUR/W installed)
Pb (net-billing)	9 kW to 36 kW	60 (+ 0,16 EUR/W installed)
Pb (net-billing)	36 kW to 100 kW	60 (+ 0,08 EUR/W installed)
Tc (net-billing)	100 kW to 500 kW	98 (no lump sum)

3.3.2 Net-billing with feed-in premium

Winning candidates in the new 2021- 2026 framework for Self-Consumption Tender (systems from 500 kW to 10 MW from November 2021, up from the 100 kW to 1 MW range in the previous tenders) receive a bonus on self-consumption at the tendered rate plus net-billing set by tender specifications (wholesale market + premium).

3.4 Collective self-consumption, community solar and similar measures

3.4.1 Collective self-consumption (PV systems for several apartments in the same building)

The legal framework surrounding collective self-consumption in France is that of virtual self-consumption within a building, a 2 km, or exceptionally, a 20 km geographical perimeter. Where generators and consumers are in the same building, the PV installation can be connected to the medium voltage grid. In other cases, installations are connected to the low voltage grid and are limited to a total of 3 MW. Virtual metering is implemented by the grid manager and requires smart meters on all generation and consumption sites. Each operation must have a legal entity, whose primary role is to supply the grid manager with algorithms or rules defining the distribution of the PV power, and an updated list of registered members of the operation.

By the end of 2021, with a total of 3,8 MW across 77 projects, 849 consumers and 128 generators were involved.

Economic models for self-consumption systems are uncertain, as the competitivity of the self-consumed electricity is very dependent on consumer electricity costs. In other words, grid parity is reached in certain sectors, and not in others.

In October 2021 the new rules for access to feed in tariffs and net billing tariffs included changes that allow systems to access the feed in tariffs / net billing tariffs for excess production from collective self-consumption systems. However, in this case the system may not benefit

from any other form of public subsidy – which were necessary to compensate the organisational and administrative over costs of collective self-consumption systems.

3.4.2 Solar Community

Solar communities (or citizen investment) continue to grow, with a specialised fund and regional and national networks supporting the inception and development of projects. The national government included the development of community solar as a priority in its renewable energy plan launching an awareness raising campaign including a dedicated section hosted on the Ministry for Ecological Transition's website, whilst it continues to maintain support, through ADEME, for the not-for-profit organisation Energie Partagée that coordinates and disseminates information and tools.

Work is on-going for the creation of the legal framework for citizen and renewable energy communities in France.

3.5 Tenders, auctions & similar schemes

Competitive tenders are the chosen tool for the French government to encourage the development of photovoltaic systems, although projects are increasingly developed outside of the framework in PPA's considering the ballooning market cost of electricity.

The Minister of Ecological Transition establishes the Tender specifications, the CRE (Energy Regulator) manages the Tenders and transmits a list and analysis of the highest-ranking candidates to the Minister, who then determines and publishes the winning candidates.

Since 2016, the winners of the calls for tenders are no longer supported by a feed-in-tariff but by a contract for difference mechanism (CfD). With the CfD, the generators of photovoltaic electricity sell their production on the market, and when the reference market costs are under the tendered costs, they receive additional remuneration from the state which compensates for the difference between the market price and the tendered cost. Conversely, when the reference market costs are above the tendered costs, operators are required to pay the difference back to the state.

With the unprecedented rise in market costs in late 2021, the prices on the electricity market have become much higher than the tendered prices. As a result, whilst the generators concerned have seen their revenues increase from their sales on the market, a significant portion of this revenues is paid to the state under the CfD mechanism. Not only does the French state not subsidise these contracts for those months, but it also receives a portion of the revenues generated by photovoltaics.

The CRE publishes a summary analysis after tenders are awarded, making available aggregated and comparative information on the provenance of materials, average bids, etc.

A new Tenders framework was initially planned for 2020 but was pushed back to late 2021, with several tenders being held under the previous framework in 2021. By October and the publication of feed in tariffs for systems up to 500 kW, the new Tender framework (called PPE2) was ready for deployment, with a first round of tenders for building applied systems in October, self-consumption systems in November, and for ground-based systems in December.

Tender selection criteria are on a lowest price basis for commercial and self-consumption systems, but price weighted with additional environmental or land use criteria (low module carbon footprints and degraded urbanised sites are benefited), or even innovation levels, for larger systems. The conditions for the PPE2 tenders were a continuation of the revised conditions for the last PPE1 Tenders.

The Energy Minister establishes the Tender specifications, the CRE (Energy Regulator) manages the tenders and transmits a list and analysis of the highest-ranking candidates to the Minister, who then determines and publishes the winning candidates. Remuneration (through Feed-in PPA, Feed-in premiums, bonuses etc.) is paid to operators by EDF (or, in certain areas, local public distribution grid managers, or other authorised organisations).

The CRE publishes a summary analysis after tenders are awarded, making available aggregated and comparative information on the provenance of materials, average bids, etc.

There were 8 national call for tenders in mainland France over 2021, including the innovation tender, and no tenders in the overseas territories.

The 2021 mainland tenders were nearly all under-subscribed, with the exception of those for ground-based systems and the first building applied tender of the year, with a particularly low under 25% for the last self-consumption tender. Two factors contributed to this - the sharp rise in electricity prices, meaning no subsidy is needed in most cases, and a change in the specification requiring a unicity of the legal entities of the consumer and the generator, with significant impacts on the fiscalism of the self-consumed electricity when third party investors are involved.

Table 22: Results for the last rounds of the 2017-2021 competitive tenders

System type and size	Building mounted systems, greenhouses and parking canopies	Building mounted systems	Ground-based systems and parking canopies	Building mounted systems for self-consumption
Individual system size limits	100 kW to 500 kW	500 kW to 8 MW	Ground: 500 kW to 30 MW Canopies: 500 kW to 10 MW	100 kW to 1 MW
Volume	1 175 MW in 11 calls of 75 MW to 150 MW	1 200 MW in 11 calls of 75 MW to 150 MW	5,78 GW in 9 calls of 330 MW to 850 MW	450 MW in 12 calls of 20 to 50 MW
Remuneration type	PPA*	CfD**	CfD**	Self-consumption + bonus on self-consumption + CfD
Number of Bids	12 and 13th calls: 238 MW selected for 507 MW of bids	12 and 13th calls: 188 MW selected for 260 MW of bids	10th call: 637 MW selected for 1 014 MW of bids	10th call: 17 MW selected for 25 MW of bids
Average tendered price (or bonus for self-consumption)	13th call: 86,02 EUR/MWh	13th call: 76,66 EUR/MWh	10th call: 56,64 EUR/MWh	10th call: 10,45 EUR/MWh

* PPA = Power Purchase Agreement at tendered rate. Contract with an obligated purchaser, the PPA being guaranteed by the French government.

** CfD = Contract for Difference = Market sales + Additional Remuneration; Contract at tendered rate.

Table 23: PPE2 (2021-2026) competitive tender volumes and results

System type and size	Building mounted systems, greenhouses and parking canopies	Ground-based systems and parking canopies	Building mounted systems for self-consumption	Innovative solar systems	Technology neutral
Individual system size limits	From 0,5 MW No upper limit	0,5 MW to 30 MW No upper limit on degraded sites	0,5 MW to 10 MW	100 kW — 3 MW (Building mounted) 500 kW — 3 MW (Ground based)	
Volume	4,2 GW to 5,6 GW in 14 calls of 300 MW to 400 MW	9.25 GW in 10 calls of 925 MW	0,7 GW in 14 calls of 50 MW	0,4 GW in 5 calls of 80 MW (Building mounted) 0,3 GW in 5 calls of 60 MW (Ground based)	2,5 GW in 5 calls of 500 MW
Number of Bids	1st call: 157 MW selected for 268 MW of bids	1st call: 705 MW selected for 845 MW of bids	1st call: 7 MW selected for 11 MW of bids	First results not available	First results not available
Average tendered price (or bonus for self-consumption)	1st call: 86,53 EUR/MWh	1st call: 58,84 EUR/MWh	1st call: 12,85 EUR/MWh	-	-

All systems are remunerated through CfD = Contract for difference = Market sales + Additional Remuneration; Contract at tendered rate.

3.6 Other utility-scale measures including floating and agricultural PV

These systems are financed through competitive tenders, generally in a specific call for innovative systems.

The national Agency for Ecological Transition (ADEME) commissioned a study to define agrivoltaics (or agriphotovoltaics), with a wide participation across the industry and the agricultural sectors. Whilst the study and recommendation were completed in September 2021, it was not published until mid-2022 after extensive high-level discussion.

Agrivoltaic and floating systems were developed and commissioned in 2021, financed through the Innovation competitive tenders.

3.7 Retroactive measures applied to PV

3.7.1 Renegotiation of tariffs for systems above 250 kW with tariffs from 2006 and 2010

Following on from the 2020 announcement, contractual negotiations were held through 2021 to revise support levels, by negotiating, on an individual basis, the level of remuneration for systems over 250 kW. Benefitting from 2006 and 2010 feed in tariffs.

Full data on the number of contracts re-negotiated has not yet been made public.

3.8 Indirect policy issues

3.8.1 Rural electrification measures

Rural electrification in France is primarily concentrated in overseas territories and isolated alpine areas. Overseas territories include remote or difficult to access zones with small villages with either no mini-grid or fossil fuel powered mini-grids, particularly in French Guiana and the island of Reunion. The national budget includes a line dedicated to off grid production in rural areas, with a 1 M€ budget in 2021, equivalent to the 2020 budget. In parallel, budgets are available for indirect measures such as electric vehicle charging points, partially financing grid connection in weak networks for renewable energies, storage and other innovations.

3.8.2 Support for electricity storage and demand response measures

There are no universal support mechanisms for electricity storage in France. However, public demand has seen a slow development in both the residential and commercial sectors, despite the low economic returns.

Large scale storage

In mainland France, by the end of 2021 about 115 storage facilities are connected to the medium-voltage grid with a capacity of 145 MW. 60% of the cumulated installed capacity was commissioned in 2021. According to the National Registry for Generators and Storage, only three of these storage facilities are listed as being associated with photovoltaic systems connected to the medium voltage grid. Four projects for 23 MW total were commissioned in 2021 in overseas territories.

Individual / small scale storage

Conditions are not favourable for the development of small-scale storage in France (no subsidies, previously relatively low electricity consumption costs and winter peak consumption profiles on mainland France). There were about 11 000 storage facilities in France (8 200 on the mainland) on residential or small-scale installations. After a peak of 2 500 new installations per year in 2018 and 2019, the rate of installation continued to decrease through 2020 and down to 830 on mainland France in 2021.

Demand Response Measures

Time-of-use electricity rates are offered to consumers in France, with a particular emphasis on displacing winter peak consumption to late night/early morning. France has very high winter evening peak demand, reflecting the high penetration of resistive electric heating.

Demand response mechanisms (flexibility) include both reduction and increases in consumption to respond to specific conditions – either through equipment shutdown or storage; given the habitual consumption profile and nuclear generation capacity in France, most is for reducing demand. Projects offering less than 1 MW of flexibility must be aggregated with other projects, but projects offering over 1 MW can be certified individually.

In November 2020 the government announced the results of the competitive tenders for demand response measures to provide primary reserve production capacity for 2021. These Tenders are an explicit support measure for the development of demand response capacity.

In 2021, there were 50 successful projects for 1,5 GW of capacity, doubling the 2020 volumes.

3.9 Financing and cost of support measures

Operator remuneration (through feed-in tariffs, Additional remuneration —market premium, bonuses etc.) is paid to operators by a designated Co-contractor (EDF, other authorised organisations or, in certain areas, local public distribution grid managers). The Co-contractor is compensated for over-costs from a dedicated account in the national Budget (Energy Transition). This account is financed by a tax on petrol and its derivatives when used as an energy source for transport or heating.

Over-costs are calculated based on a typical production curve weighting of monthly average day time spot prices on the national electricity market. The estimated total cost of compensation for 2021 for photovoltaic contracts (feed-in tariffs and premiums) for continental France is 2 706,2 M EUR (source annual finance law 2022, national government). Much of this cost finances contracts signed in 2009 and 2010.

With the increase in market costs for electricity, over costs have reduced and led to twice-revised estimates for the 2021 cost of support measures.

With market costs expected to remain high (roughly 4 times their 2019 level), the cost of support measures for new photovoltaics is increasingly marginal – and recent and new contract for systems within competitive tenders may just reimburse a large part of previous costs over the coming years.

4 INDUSTRY

4.1 Production of feedstocks, ingots and wafers (crystalline silicon industry)

Table 24**: Silicon feedstock, ingot and wafer producer's production information for 2021.**

Manufacturers	Process & technology	Estimated Total Production
Photowatt EDF ENR PWT	mc-Si wafers [MW]	75 MW

Photowatt EDF ENR PWT is a vertically integrated manufacturer, manufacturing its own cells, wafers and modules. Its processes produce monocrystalline bricks (Crystal Advanced Process). Its subsidiary, Photowatt Crystal Advanced (in partnership with CSI and ECM Greentech), is specialised in low carbon production of advanced technology silicon ingots and wafers. The COVID crisis in 2020-2021 has impacted the strategic position of EDF with regards to Photowatt, and is likely to result in ownership or operational changes in 2022.

Irysolar, part of the ECM Greentech group, focuses on supplying photovoltaic equipment manufacturing for the end-to-end value chain, from ingots to cells.

4.2 Production of photovoltaic cells and modules (including TF and CPV)

Module manufacturing is defined as the industry where the process of the production of PV modules (the encapsulation) is done. A company may also be involved in the production of ingots, wafers or the processing of cells, in addition to fabricating the modules with frames, junction boxes etc. The manufacturing of modules may only be counted to a country if the encapsulation takes place in that country.

Table 25: PV cell and module production and production capacity information for 2021

Cell/Module manufacturer	Technology (sc-Si, mc-Si, a-Si, CdTe, CIGS)	Production and/or capacity (MW/year)	
		Cell	Module
Wafer-based PV manufactures			
EDF ENR PWT (Photowatt)	sc-Si	2	2
Reden Solar	sc-Si		90
Recom Sillia	sc-Si		300
S'tile	sc-Si		15
Systovi	sc-Si		80
Sunpower (Total)	sc-Si		80
VMH Energies	sc-Si		60
Voltec Solar	sc-Si		200
Thin film manufacturers			
ARMOR	OPV	40	40
Dracula Technologies	OPV	/	/
Totals			**Approximately 850 MW**

Sources: *Le photovoltaïque : choix technologiques, enjeux matières et opportunités industrielles,* French Ministry of Energy and Environment; interviews with manufacturers and Hespul treatment.

The national industry is relatively small, with several manufacturers targeting specific niche markets, often related to building integration products (PV tiles, façade elements…), PV/thermal hybrid modules (Dualsun, Systovi…) or small-scale production runs and pre-industrial research (Photowatt, Irysolar…). This industry operates with strong public R&D / industry links.

In the past years, several manufacturers have increased their production capacity based on the favourable market visibility given by the national competitive tenders. However, this situation tends now to become less favourable as observed in the heavy decrease of French modules' share in the results of 2019 and 2021 competitive tenders.

Small-scale producers of modules dedicated to the national or western market:

- **Recom Sillia**'s Lannion site production has a 300 MW/year capacity;
- **Sunpower (Total Group subsidiary)** has two factories in France: Tenesol Technologies in Toulouse and SunPower Manufacturing de Vernejoul, Moselle, and manufactures modules from PV laminates. The modules use single-crystal silicon back-contact cells manufactured by overseas Sunpower factories, with industry high

performances of up to 24%. The two factories have a production capability around 40 MW each. The manufacturer announced at the end of 2021 the conversion of the Vernejoul line to the production of *Maxeon air* modules with the objective of producing 100 MW/year by 2023. The silicon modules should be much lighter than conventional modules, with the possibility of being glued directly to the waterproofing of roofs whose structure is too weak for conventional systems;

- **Voltec Solar** assembles modules on their Alsace site, its production capacity is 200 MW/year, with the objective of doubling this capacity and producing heterojunction modules. The company has launched the Belenos project with Systovi, which aims to reach a cumulative capacity of 1 GW/year for both manufacturers;
- **Reden Solar** manufactures modules, but also develops and operates photovoltaic power plants. It's semi-automated and automated production lines manufacture modules but also PV powered streetlamps, street furniture and solar thermal equipment;
- **VMH Energies** production site is located in Châtellerault near Poitiers. Its production capacity is 60 MW per year.

Integrated cells and modules manufacturers:

Photowatt/EDF ENR PWT's Bourgoin Jailleu site, has an R&D cells and modules production site with a capacity of 2 MW per year. Photowatt/EDF ENR PWT now concentrates on research and development to "foster the emergence of new technological solutions" and test them in pre-industrial conditions.

Other markets: Photovoltaic tiled roofs, photovoltaic thin films and aero-voltaic modules:

- **Systovi** assembles monocrystalline modules. It mainly manufactures PV/thermal hybrid modules (hot air). Its manufacturing facilities are located at Carquefou, close to Nantes. The company, owned by the Cetih group, invested in a new production line with a capacity of 65 MW/year. It is also considering expansion to 200 MW/year with the possibility of using heterojunction technology. The company has launched the Belenos project with Voltec, which aims to reach a cumulative capacity of 1 GW/year for both manufacturers;
- **S'Tile** develops a 15 MW pilot line where their proprietary "i-Cells®" are assembled into modules since early 2017. The company develops a line of modules from 25 W to 200 W with customised formats for BIPV or off grid applications, such as integration into streetlights. They have a small range of standardised modules targeting high end building integration clients;
- **ARMOR** develops proprietary organic "ASCA" films, targeting the market for connected devices, wearable photovoltaics as well as building integration applications (semi-transparent glazing…), with a manufacturing capacity of 1 million m^2 / year. The company invested 10 million euros a year in R&D and its production capacity;
- **Dracula Technologies** is a start-up developing printed organic photovoltaic cells (trademarked LAYER technology) aimed at the connected device market. Its pilot line was inaugurated in September 2019;
- **Solems SA** manufactures thin-film elements and modules up to 30 cm x 30 cm for connected devices and self-powered automates and building elements;
- **SolarCloth** develops flexible solar on different supports for integration onto canvas (tourism and agricultural uses) and vehicle roofs (with Renault Trucks).

Other operator's such as **Edilians**, manufactures PV tiles (size 45 cm × 31 cm and 136 cm × 50 cm respectively), while DualSun develops and markets photovoltaic-thermal hybrid modules (PV-T).

The Norwegian manufacturer REC was planning to build a heterojunction module factory in France with a capacity of 2 GW/year (in 2022) then 4 GW/year (in 2025). This production site, planned in Moselle, could produce the equivalent of France's needs to meet the Energy Programme Decree, however the project seems to have stalled in 2021 without any official announcements.

4.3 Manufacturers and suppliers of other components

Balance of system component manufacture and supply is an important part of the PV system value chain. There are a number of French companies with an international presence providing a full range of electrical solutions for connection, conversion and management of photovoltaic systems. The France solar industry initiative is designed to showcase French know how across all solar technologies, and members are present from upstream (research and machine tools) all the way through the value chain from industry to support, installation and O&M.

PV inverters (for grid-connection and stand-alone systems)

Only a small handful of inverter manufacturers are French – a large multinational with a complete offer (string and centralised inverters), and other manufacturers with a small range of products targeting specific markets with (off grid, on grid, storage…).

Storage batteries

Market penetration remains very low for residential systems, although offers are present, and whilst national industry has international players (SAFT, EDF), deployment of large-scale storage is limited – mostly to overseas territories, although some projects on the mainland are supplying flexibility measures.

Supporting structures

A number of local manufactures of supporting structures exist; products range from PV tiles (Edilians, SunStyle), roof integration supports (IRFTS, bought by Edilians in early 2022 and GSE), pergolas (Mitjavila, Adiwatt) and residential car ports (IRFTS, Adiwatt, Carport Solaire…).

Solar parking supports are designed and manufactured by a number of companies present, with a range of materials used (wood, steel, aluminium).

Manufacturers of on-roof systems for industrial metallic roofs and bituminous or polymer roofs are also present, including Dome Solar, Solapro, Arcelor or Soprasolar.

A number of manufacturers of solar support *buildings* (agricultural hangars, greenhouses) are also present (Mecosun…) although rising and fluctuating steel costs have led to much uncertainty over 2021.

With a unique lead on the international market, Ciel & Terre is a leading designer and manufacturer of floating photovoltaic supports and systems.

5 PV IN THE ECONOMY

This chapter aims to provide information on the benefits of PV for the economy.

5.1 Labour places

Table 26: Estimated PV-related full-time labour places in 2021

Market category	Number of full-time labour places
Research and development (not including companies)	500
Manufacturing of products throughout the PV value chain from feedstock to systems, including company R&D	700
Distributors of PV products and installations	5 100*
Other	3 300*
Total	**9 600**

Sources: Etude ADEME “Marchés et emplois concourant à la transition énergétique dans le secteur des énergies renouvelables et de récupération” (2021), Évaluation et analyse de la contribution des EnR à l’économie de la France et des territoires 2020, SER and Hespul estimates (*).

While jobs related to the manufacture of photovoltaic equipment, R&D or the installation of photovoltaic systems are stagnating, those dedicated to project development, studies and operations are growing rapidly due to the almost threefold increase in installed capacity compared to previous years. The rapid growth of the sector, and the lack of qualified manpower, has led to tensions in recruitment. Conversely, material shortages at the end of the year led some companies to significantly reduce their activity, even putting some employees on reduced hours.

The most recent Renewable Energy Market and Employment Study was published in 2021 and covers 2019 direct employment data. This data has been completed and updated based on market evolutions in 2021. Other studies indicate a total of 17 000 direct and indirect jobs without providing a breakdown between the different market segments.

5.2 **Business value**

In 2021, the installed capacity has tripled compared to previous years. This boom in the French market is also reflected in the estimated value of the PV business, which has also increased almost threefold, with little change in the unit costs of the PV systems compared to previous years.

Investments and turnover are studied by ADEME every two years in the study “Marchés et emplois liés à l’efficacité énergétique et aux énergies renouvelables“.

The market value for 2021 (below) has been estimated based on 2021 trending prices and extrapolated official 2021 grid connection volumes. Data accuracy may be compromised by the use of trends costs (these costs are from a reduced sample across France and may not accurately reflect real costs) and the volume estimate spread across segments for Industrial systems with power above 250 kW and ground-mounted systems. An EY study commissioned by the French Renewable Energy Trade Association estimates the added value of the sector at 1,4 billion euros in 2021, but does not give a breakdown of the wealth created by power segment. EY's estimate is the result of macro-economic modelling, based on an input-output table (IOT) considering imports and exports for each segment of the value chain. Their estimate is likely to be more accurate than the one presented below, however the one below remains relevant as a first approach and is sufficient to compare with other PVPS countries.

The following table represents the value of investments in PV systems.

Table 27: Rough estimation of the value of the PV business in 2021 (VAT is excluded)

Sub-market	Capacity installed in 2021 [MW]	Average price [€/W]	Estimated value M EUR
Off-grid			
Residential < 3 kW	85	2,4	200
Residential < 9 kW	151	2,1	320
Commercial < 100 kW	699	1,15	800
Commercial < 250 kW	197	0,9	180
Industrial > 250 kW	904	0,95	860
Grid-connected distributed	**2 036**	**1,16**	**2 360**
Grid-connected centralized	**1 315**	**0,7**	**920**
Estimated Value of PV investments in 2021			**3 000 to 3 500****

SOURCE: SDES, Observ'ER Baromètre Électrique 2021, France Terre Solaire Bilan 2021 *estimate HESPUL, Etude ADEME “Marchés et emplois concourant à la transition énergétique dans le secteur des énergies renouvelables et de récupération” (2021), Évaluation et analyse de la contribution des EnR à l’économie de la France et des territoires 2020 SER, Coûts des énergies renouvelables et de récupération 2019 ADEME.

** A range is published due to the approximate nature of data.

6 INTEREST FROM ELECTRICITY STAKEHOLDERS

6.1 Structure of the electricity system

With a highly concentrated electricity EDF, (the state holds over 80% of EDF share capital) and its different wholly or partially owned subsidiary companies are the principal generator, transport grid manager, distribution grid manager and retailer. In response to the open market European Directives, the different entities are legally separate, with grid management missions run as “delegated public services”. The EDF group has an extensive portfolio of nuclear and renewable energy sites.

Secondary operators include the generator Engie (the state holds over 20% of the share capital) and municipal DSO’s (they cover about 5% of the population).

The National Energy Regulator, Commission de régulation de l’énergie (CRE) is an independent administrative authority and supervises market regulations, grid access conditions and manages competitive tender processes based on rules established by the government. They also judge grid access conflicts and are a mandatory consultative body for changes to the legislative and regulatory energy framework.

6.2 Interest from electricity utility businesses

In France the only private electricity utility is EDF (the state is the majority owner with over 80% of share capital), that covers 95% of the population - all other utilities are (generally very small) public entities – a legacy of the post-war nationalisation of private electricity companies.

EDF and its subsidiary companies are major players in photovoltaics, with branches dedicated to different market segments present in France and across the world. EDF Renouvelables (EDF Renewable for the international branch – centralised photovoltaics), EDF Renouvelables Services (O&M services in Europe), EDF Energie Nouvelles Réparties (EDF ENR - residential and small commercial systems), Sunzil (operating in the Caribbean and other isolated/off grid areas) are all active in France. EDF Store & Forecast provides software solutions for piloting renewables and storage. EDF EN Photowatt is a photovoltaics manufacturer.

EDF is also active in R&D activities through both EDF internal research departments, research partnerships with public research organisations and Photowatt. Through its different subsidiaries, EDF has a worldwide portfolio of 43,6 GW of solar projects in early and late stage development, compared to 8 GW in construction and 6 GW already installed (total or partial ownership) of which there is nearly 400 MW in France (proportional to ownership).

ENGIE is a gas utility also present in the development and generation of electricity capacity - and has the biggest solar portfolio in France at around 1 GW (3 GW worldwide).

6.3 Interest from municipalities and local governments

Almost all local authorities have climate energy plans that are generally ambitious in terms of photovoltaic development. This is one of the reasons why municipalities and local governments continue to be active participants in the growth of photovoltaics in France, both investing in projects, experimenting innovative projects (particularly collective self-consumption), and facilitating citizen investment and grid integration. Many have created public-private development and investment companies to both facilitate project development without the constraints of public procurement, but also serve as a vehicle for their projects.

7 HIGHLIGHTS AND PROSPECTS

7.1 Highlights

With the publication of future development scenarios, new frameworks for feed in tariffs, building integrated photovoltaics and competitive tenders, more new buildings falling under mandatory solar roofs requirements, new targets for solar on public buildings and an awareness raising campaign for community solar, and record new capacity, 2021 was a busy year for solar in France.

The national energy Programme Decree (PPE) for photovoltaics targets 20,6 GW of photovoltaics in 2023 and a 2028 target of 35,6 GW to 44,5 GW. Long term scenarios were established by both the national transport system owner (RTE) and environmental agency (ADEME), highlighting the need for at least 70 GW and up to 200 GW in 2050 if carbon neutrality is to be achieved by then.

In 2021, national photovoltaic capacity grew by a nearly unprecedented 3,3 GW DC, (triple the 2020 volume, up from 1 GW), for a cumulative capacity of nearly 17 GW DC for grid connected installations. More than 2/3 of new capacity is industrial and utility scale systems.

Approximately 10% of the new capacity is with some form of self-consumption – and although self-consumption models remain marginal for industrial systems, over 90% of capacity for new residential and small (under 100 kW) commercial systems have self-consumption, generally associated with feed in tariffs for net billing.

In France projects progress from gaining urban planning approval (permitting) to entering the grid connection queue to commissioning. Over 4 GW DC of new projects entered the grid connection queue in 2021, bringing the queue to around 10 GW DC of projects, including nearly 3 GW with DSO contracts. The new framework for feed in tariffs led to an explosion in the number of grid connection requests in the newly accessible 100 kW to 500 kW segment, with the previous quarterly volumes of between 30 MW and 80 MW ballooning to 700 MW in the 4th quarter, after the new framework came into effect. With longer lead times than smaller projects, and time to prepare, grid managers have been mostly able to treat the requests in a timely manner.

7.2 Perspectives

Worldwide tension in the solar supply markets will impact new capacity in 2022, with strong demand from the local market as electricity costs soar exacerbating long delivery times for inverters and continued rising module costs.

Project developers have either put off projects as the new materials costs outstrip any possibility of a profit margin, or on the contrary sped up projects where possible to beat future rising costs, leaving the market hard to predict. The newly opened segment of systems 100 kW to 500 kW will likely drive the market in late 2022, with around 600 MW that should be ready for commissioning late 2022 or early 2023 – if installers can access modules and inverters, but many industry actors consider that 2022 installed capacity is likely to fall far short of 2021's over 3 GW, because of rising costs and supply chain issues.