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

2023

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 TCPs 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, China, Denmark, Finland, France, Germany, Israel, Italy, Japan, Korea, Malaysia, Morocco, the Netherlands, Norway, Portugal, South Africa, Spain, Sweden, Switzerland, Thailand, Turkiye, and the United States of America. The European Commission, Solar Power Europe, the Solar Energy Research Institute of Singapore and Enercity SA 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 2023. Information from this document will be used as input to the annual Trends in photovoltaic applications report.

Authors

- **Main Content:** M. de l'Epine
- **Data:** ENEDIS, SDES, RTE
- **Analysis:** E. Lasarra A. Barguès

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COVER PICTURE

Solar shadecloth by Solarcloth (www.solar-cloth.com) installed on a bus parking station for the Paris 2024 Olympics: image credits Spatiotempo

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ACKNOWLEDGEMENTS

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MAIN 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° 646, May 2024 (SDES — Service de la donnée et des études statistiques, Commissariat au Développement Durable, Ministery for Ecological Transition and Territorial Cohesion of France;
- 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 2023" (RTE Electricity Report 2023), RTE, February 2024 (Transport grid manager);
- "Charges de service public de l'énergie pour 2024 et à la réévaluation des charges de service public de l'énergie pour 2023", CRE, July 2023;
- "Etude qualitative 2023 du marché des installations solaires photovoltaïques inférieures ou égales à 9 kW" Observ'ER, November 2023;
- " EU Solar Jobs Report 2023 » SolarPowerEurope;
- "Observatoire de l'énergie solaire photovoltaïque en France" France Territoire Solaire, February 2024 and June 2024;
- "Baromètre des achats d'énergie verte en France" T1 to T4 2023 Capgemini invent;
- 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 2023);
- https://forum-photovoltaique.fr

1 HIGHLIGHTS

The year 2023 in photovoltaics in France was marked by several important elements – the progressive drop in market electricity prices, the drastic drop in international module prices and the publication of the Law for the Acceleration of Renewable Energies. This last Law was planned and consulted through 2022 and published in 2023, although many of the decrees were only published in 2024. Key elements for solar in this text that become operational in 2023 include:

- Mandatory solar on many types of new or renovated buildings over 500 m^2;
- Mandatory solar parking canopies for car parks over 1500 m^2;
- A legal definition of agrivoltaics;
- The exemption allowing certain unused land surfaces next to roads, canals and train lines to have PV systems built on them;
- A requirement that competitive tender winners share some of the added value with locals.

The evolution of market electricity prices and module prices meant that whilst investment costs decreased, the drop in electricity market prices didn't necessarily lead to more attractive markets for PPA contracts – with the consequence that Competitive Tenders gained in attractivity, guaranteeing remuneration and facilitating financing. Despite this, PPA's remain an option as consumers hedge against future electricity price volatility.

In 2023, national photovoltaic capacity grew by a record 4.0 GW DC (up from 2022's revised volume of 3.2 GW DC), for a cumulative capacity of roughly 24.5 GW DC for grid connected installations – a total that seemed near at the end of 2022, but that revised data meant that this volume was only reached at the end of 2023. Whilst last year over half the new volume was in industrial and utility scale systems, in 2023 residential systems accounted for 24% (up from 14%) and commercial systems between 100 kWp and 250 kWp went back up to 25% of new volume, up from 8% in 2022. Industrial and utility scale systems dropped their share of the market again in 2023, down to just 37% after hitting 54% in 2022 and 66% 2021), as self-consumption in residential and commercial markets increases – total or partial self-consumption represented nearly 40% of new capacity, up from just over 20% in 2022 and 10% in 2021.

In France projects progress from gaining urban planning approval (permitting) to entering the grid connection queue to commissioning. Approximately 7 GW DC of new projects entered the grid connection queue in 2023, and with only 4.0 GW DC of commissioned projects, the stock grew o more than 26 GW DC of projects, of which nearly 7 GW DC have already signed DSO contracts (up from 4.6 GW AC (revised) last year), and an unknown capacity with the TSO.

2 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 2023 statistics if the PV modules were installed and connected to the grid between 1 January and 31 December 2023, although commissioning may have taken place at a later date.

Data collection includes information on storage capacity, and the 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 peak DC power thresholds. It may be useful for the reader to know that the average generation across France is 1 100 kWh/kWp, but that systems installed in the southern half of mainland France will generate more, up to 1 550 kWh/kW, and in overseas territories up to and over 1 700 kWh/kWp. 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.

2.1 Applications for Photovoltaics

The principal applications for photovoltaics in France in 2023 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 1 MW);
- **Utility scale ground mounted** systems (over 1 MW).

Small but growing segments include micro (balcony) kits, agrivoltaics and floating PV.

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

After a very dynamic year in 2022 in the residential segment, 2023 saw a continuation of the same pace of growth. The commercial and utility segments still dominated newly installed capacity, with 50% of newly installed power connected to the medium or high voltage grid. Residential systems account for less than 25% of the total, despite the fact that residential systems account for over 90% of new photovoltaic installations in number in France in 2023.

2.2 Total photovoltaic power installed

- **Centralised**: any PV installation which only injects electricity and is not associated with a consumer (no self-consumption) over 1 MW;
- **Decentralised**: any PV installation which is embedded into a customer's premises (either with or without self-consumption) under 1 MW.

Cumulative PV installed capacity as of the end of 2023 reached 20 067 MW (AC or inverter power) or roughly 24,6 GW DC (module power).

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%.

Capacity data published by the SDES and in the national register is given as the AC power of system. 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 2023:

Grid connected distributed (decentralised) systems:

- **Residential**: up to 9 kW - no data was available concerning the split BIPV/BAPV for new systems from 2017 to 2022, the BIPV volumes with the bonus Feed-in tariffs are presumed to be the maximum allowed volumes in the feed in tariffs for 2022 and 2023 but do not include bespoke BIPV;
- **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 1 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 1 MW and/or floating systems under 1 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 2023

		Installed PV capacity in 2023 [MW DC]
	Decentralised	2520
	Centralised	1 446
	Off-grid	
	Total	3 966

SOURCE: SDES, Observ'ER, Enedis, *split is estimated BI France

Table 2: PV power installed during calendar year 2023

			Installed PV capacity [MW]	Installed PV capacity [MW DC]
Grid-connected	BAPV	Residential	2 420	921
		Commercial		1 454
		Industrial		45
	BIPV	Residential	100*	100
		Commercial		
		Industrial		
	Utility-scale	Ground-mounted	1 446	1 410
		Floating		36
		Agricultural		
Off-grid		Residential	NA	
		Other		
		Hybrid systems		
Total			3 966	

SOURCE: SDES Observ'ER, Enedis, some splits estimated BI France *it is assumed that all the available BIPV bonus was consumed, spread 40% on residential and 60% on small commercial systems.

Table 3: Data collection process

If data are reported in AC, please mention a conversion coefficient to estimate DC installations.	All power data is given in AC power. The conversion coefficient is 1.2. For systems over 1 MW, the conversion coefficient is 1.25 based on survey of systems commissioned in 2023.
Is the collection process done by an official body or a private company/Association?	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. Enedis (national DSO) publishes segmented data. author has further segmented data as required.
Link to official statistics (if this exists)	https://www.statistiques.developpement-durable.gouv.fr/les-energies-renouvelables?rubrique=21
Data quality	Data is of good quality, however provisional, and may be revised as grid operators provide additional information. Some divergence in capacity volumes may exist depending on the segments represented; the error source may be related to reporting dates, provisional data and/or collection methods. Historical data may be in DC.

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 centralised [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	13 513*
2021	30.15*	8 873	7 865	16 960*

2022	/	11 211	8 388	20 610*
2023	/	12 188	12 387	24 576

*revised in 1 st quarter 2024

Table 5: Other PV market information

	2023			
Number of PV systems in operation in your country	Peak Power range	Installations (number)	Power [MW AC]	Power [MW DC]
	0 – 3 kW	526 506	1 338	1 606
	3 kW–9 kW	274 211	1 585	1 902
	9 kW–36 kW	35 492	834	1 001
	36 kW–100 kW	37 130	3 190	3 828
	100 kW–250 kW	13 816	2 634	3 161
	> 250 kW	3 288	10 487	13 079
	Total	890 443	20 067	24 576
Decommissioned PV systems during the year [MW]	0 (estimated)			
Repowered PV systems during the year [MW]	10 - 100 MW. Currently no official reporting of repowered volumes is published			
Unregistered capacity	Analysis of the data from the 3 major sources (SDES, Enedis and the Register). Unregistered capacity possible with micro (balcony) systems.			

Sources: SDES, Registre national des installations de production et de stockage d'électricité, Open data réseaux énergies (ODRÉ) *Becquerel Institute France extrapolations.

Table 6: PV power and the broader national energy market

	2022	2023
Total power generation capacities [GW]	Total: 144.6 GW of which • Nuclear: 61.37 GW • Fossil fuel: 17.46 GW • RES: 65.8 GW (see below)	Total: 149.4 GW of which • Nuclear: 61.4 GW • Fossil fuel: 17.4 GW • RES: 70.6 GW (see below)
Total renewable power generation capacities (including hydropower) [GW]	• PV*: 16.8 GW • Hydro: 25.7 GW • Wind: 21.1 GW • Other RES: 2.2 GW	• PV*: 20 GW • Hydro: 25.7 GW • Wind: 22.7 GW • Other RES: 2.2 GW
Total electricity demand [TWh]	460.2	445.7
New power generation capacities installed [GW]	Total: 5.6 GW of which • Gas: +0.4 GW • PV and other RES: 5.2 GW (see below)	Total: 4.8 GW of which • Gas: 0 GW • Coal: 0 GW • Diesel: 0 GW • Nuclear: 0 GW PV and other RES: 4.8 GW (see below)
New renewable power generation capacities (including hydropower) [GW]	• PV*: + 2.7 GW • Wind: + 2.4 GW • Hydro: + 0.1 GW • Other RES: 0 GW	• PV*: + 3.3 GW • Wind: + 1.6 GW • Hydro: + 0.00 GW • Other RES: 0 GW
Estimated total PV electricity production (including self-consumed PV electricity) in [GWh]	18 600	21 600
Total PV electricity production as a % of total electricity consumption	4,1%	4,8%
Average yield of PV installations (in kWh/kWp)	1 160 kWh/kW (30° south facing fixed systems 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)	1 100 kWh/kWp

2022 RTE France Electricity Report 2022. 2023 RTE France Electricity Report 2023.

*Data in this table is provided by RTE and provisional PV **are AC power only**.

2.3 Key enablers of PV development

Table 7: Information on key enablers.

	Description	Annual Volume	Total Volume	Source
Decentralised storage systems	Systems that were reported by Consuel (mandatory declaration)	3 245 in Mainland France and 1267	Approx. 17 000 systems	Consul Annual Report 2023
Residential Heat Pumps (number)	air/air + water/water + air/water	910 420 + 3 517 + 306 534 = 1 220 471		Uniclim Bilan 2023
100% Electric cars (number)		329 428	1 019 521	AVERE Bilan 2023
Hybrid rechargeables (number)		163 354	576 236	AVERE Bilan 2023

3 COMPETITIVENESS OF PV ELECTRICITY

In 2023, the price of photovoltaic modules dropped significantly. An average of a 40 to 50% decrease was observed for all types of crystalline modules on international markets from January to December 2023.

This drop in price can be explained by several factors. Due to a recent module shortage, European installers and wholesalers have stockpiled modules, anticipating high sales. In response, Asian manufacturers ramped up production capacity, and confronted with market barriers in North America and India, oriented their modules towards the European market, with supply largely exceeding demand. Despite long-term positive prospects, the international market isn't growing as fast as supply, in particular in Europe where project debt financing has remained at the high 2022 levels (over 4% in France), impact project profitability. Currently, it's estimated that 40 to 100 GW of unsold modules are stored in European warehouses, indicating a significant oversupply.

3.1 Module prices

Table 8: Typical module prices

Year	Typical price of a standard module crystalline silicon EUR/Wp			
	2020	2021	2022	2023
Average module price (all technologies)	0.35 - 0.4	0.25 – 0.4	0.25 – 0.4	0.15 – 0.3

SOURCE: CRE “Coûts et rentabilités du grand photovoltaïque en métropole continentale”, pvXchange and Hespul estimate. 2023 data from Becquerel Institute France limited market survey.

3.2 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. While the cost of panels on the international market has fallen sharply in 2023, the total price of installations are similar to the one noted in 2022.

The highest prices concern the residential segments, with a significant gap between the lowest and highest prices in the segment. Regarding the small commercial BAPV segment, there is a very large difference between the prices for 10 kWp and 100 kWp systems. The same comment can be made regarding the small, centralised PV segment for 1 MWp and 20 MWp systems.

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

Category/Size	Typical applications and brief details	Current prices [EUR/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.	2.6 (2.3 – 2.9)
Residential BAPV 3-10 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.	2.5 (1.3 – 3.5)
Residential BIPV 3-10 kW	Grid-connected, building integrated, distributed PV systems installed to produce electricity to grid-connected households. Typically, on villas and single-family homes.	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.	1.2 (0.9 – 1.5)
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.	0.7 - 0.9
Industrial BAPV >250 kW	Grid-connected, roof-mounted, distributed PV systems installed to produce electricity to grid-connected industrial buildings, warehouses, etc.	0.8 - 1.0
Small, centralised PV 1-20 MW	Grid-connected, ground-mounted, centralised 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.	0.65 - 0.95
Other	Parking canopy distributed >250 kW	1.2 – 1.4

SOURCE: estimation Becquerel Institute France based on limited market surveys.

Table 10: National trends in system prices for different applications

Year	Residential BAPV Grid-connected, roof-mounted, distributed PV system 5-10 kW **[EUR/W]**	Small commercial BAPV Grid-connected, roof-mounted, distributed PV systems 10-100 kW **[EUR/W]**	Large commercial BAPV Grid-connected, roof-mounted, distributed PV systems 100-250 kW **[EUR/W]**	Centralised PV Grid-connected, ground-mounted, centralised PV systems 10-50 MW **[EUR/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
2022	2.2 (1.2 – 3)	1.1 (0.8 – 1.3)	0.7 – 0.9	0.65 – 0.95
2023	2.5 (1.3 – 2.9)	1.2 (0.9 – 1.5)	0.7 – 0.9	0.65 – 0.95

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, Observ'ER, limited market surveys by Hespul, Becquerel Institute France. VAT not included *IAB: completely building integrated; **ISB: simplified building integration; BAPV building applied/roof top systems.

3.3 Cost breakdown of PV installations

Limited market surveys have been used to evaluate the cost redistributions in the context of rising upstream costs as professionals responded to these events.

Observ'ER conducts a yearly survey of professionals with partial cost breakdowns for systems under 3 kW. The survey indicates that for smaller systems installation work is up to 0.75 EUR/Wp in early 2023, where this increase in installation costs billed by installers is to compensate for reduced margins on material and equipment.

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

Cost category	Average [EUR/W]	Low [EUR/W]	High [EUR/W]
Hardware			
Module	0.98	0.57	1.89
Inverter	0.5	0.26	1.05
Mounting material	0.32	0.28	0.6
Other electronics (cables, etc.)	0.2	0.1	0.37
Subtotal Hardware	**2**		
Soft costs			
Planning	0.5		
Installation work			
Shipping and travel expenses to customer			
Permits and commissioning (i.e. cost for electrician, etc.)			
Project margin			
Subtotal Soft costs	**0.5**		
Total (excluding VAT)	**2.08**		
Average VAT	20%		
Total (including VAT)	**2.5**		

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, Becquerel Institute France).

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, centralised PV systems of >10 MW

Cost category	Average [EUR/W]
Module	0.18
Inverter	0.05
Mounting material	0.11
Other electronics (cables, etc.)	0.14
Subtotal Hardware	**0.48**
Planning	0.14
Installation work	
Shipping and travel expenses to customer	
Permits and commissioning (i.e., cost for electrician, etc.)	
Project margin	
Subtotal Soft costs	**0.14**
Grid connection	0.10
Total (excluding VAT)	**0.62**
Average VAT	20%
Total (including VAT)	**0.74**

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, Becquerel Institute France.

3.4 Financial Parameters and specific financing programs

Table 13: PV financing information in 2023

Different market segments	Loan rate [%]
Average rate of loans – residential installations	7% - 9% over 12 years, still rising (including insurance)
Average rate of loans – commercial installations	Approximately 4.0% over 12 to 20 years (not including insurance)
Average cost of capital – industrial and utility installations	3 to 4% over 20 years

SOURCE: Statinfo Le crédit aux particuliers Déc 2023 Banque de France, Taux des crédits aux entreprises by Banque de France, S&P Dow Jones Indices SIN: DE000A0ME5S6; estimation

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

Interest rates for all residential and smaller commercial sectors continued to slightly increase month on month through 2023 after more significant increases in 2023. For larger projects, interest rates increased over 2023 until they dropped approximately 1% from October through to January 2024.

3.5 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	Small-scale operations. A company specializing in photovoltaic installations will install solar panels on your roof, retaining ownership of the panels. They will also look after the maintenance of the installation for the duration of the lease. The renters pay a monthly instalment.
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)	Crowdfunding generally finances debt through crowd-funding platforms, however some platforms allow for equity financing. Examples of platforms: MiiMOSA, Enerfip, Lendosphere, Lumo, Lendopolis etc...
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).

Despite the decrease in Cleantech investments in France in 2022, investments in 2023 saw a dynamic growth, the total amount raised in 2023 will be more than 28% higher than in 2022 and

the total number of operations went from 123 in 2022 to 181 in 2023. The largest operation in the RES sector was Amarenco with 300 million euros raised from a single investor.

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) investment funds available for photovoltaic projects. In Europe, France was the second-largest beneficiary of EIB Group financing in 2023, and the country was the top beneficiary for climate and environment financing with an overall investment of €6.9 billion in renewable energy, clean mobility and energy efficiency. For example, in 2023, the EIB authorized a loan of 250 million € to Sorégies Group under InvestEU to help deploy the company's investment plan for 2024-2026 promoting renewable energy and modernisation of its electricity distribution networks.

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 (Société de Financement des Économies d'Énergie) - financial companies that provide debt financing or leasing options for energy efficiency and renewable energy projects by municipalities, social housing organisation, commercial companies and agricultural companies. These companies have a specific status that allows them to propose optimal financing solutions to projects.

Bpifrance has deployed large volumes for project financing from May 2023 with a nationwide campaign targeting 20,000 businesses of all sizes and in all sectors - the goal of this campaign is to accelerate the ecological and energy transition (EET) of businesses and the transformation of French industry. One example of project financing is the ZE Energy solar farm project, for which construction began in June 2023. Of the total investment of 84 million €, 52 million € has been raised through senior debt secured with banks (bpifrance and Caisse d'Epargne Ile-de France.

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.

In 2023, 40 new solar community projects for 35,37 MW were commissioned by Energie Partagée. The amount invested in photovoltaic citizen projects during this year reached 3.6 million € whilst an equivalent amount was collected by the fund.

Residential project financing

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

3.6 Merchant PV/PPA/CPPA

The corporate power purchase agreement (CPPA) market in France continued to grow, with important changes from 2022 as solar parks exited support mechanism contracts and entered what could be called “brownfields” CPPA, although these systems have not necessarily finished depreciation. Buyers continued to look to hedge against future volatility despite electricity prices stabilising in 2023 below 2022 prices, announcing more (but smaller volumed) CPPA’s than in 2022. The PPA Guarantee Fund operated by bpifrance (public investment bank) become operational, with the goal of providing guarantees to allow smalle commercial and industrial consumers to engage in CPPA. Contracts for greenfield systems run from 15 to 25 years, with an occasional contract announced for only 10 years. SNCF remains an important buyer, announcing new contracts including with with Voltalia.

3.7 Additional Country information

Retail electricity prices for a household	Time of use contracts available. Eurostat Band DC (2 500 kWh < consumption < 5 000 kWh) • 259.1 EUR/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): • 240.3 EUR/MWh excluding VAT and other recoverable taxes and levies
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): • 203.2 EUR/MWh excluding VAT and other recoverable taxes and levies
Liberalization of the electricity sector	France’s electricity industry is highly concentrated but not vertically integrated in theory. However, in June 2023, the French State finalised the purchase of all EDF's shares. As a result, the French State now holds the entire share capital and voting rights of EDF.

SOURCE: INSEE, CRE, Eurostat [nrg_pc_204] and (nrg_pc_205) 2023S2.

4 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 15: Summary of PV support measures

Category	Residential		Commercial + Industrial		Centralised	
Measures in 2022	**On-going**	**New**	**On-going**	**New**	**On-going**	**New**
Feed-in tariffs	yes	Yes (changes to Feed in Tariff conditions)	yes	-	-	-
Feed-in premium (above market price)		-	Yes, (CfD in competitive Tenders)	Minor changes to Tender conditions	Yes, (CfD in competitive Tenders))	Minor changes to Tender conditions
Capital subsidies		-		-	-	-
Green certificates		-		-		
Renewable portfolio standards with/without PV requirements		-		-	-	-
Income tax credits		-		-	-	-
Self-consumption	yes	-	yes	-	-	-
Net-metering		-		-	-	-
Net-billing	yes	Yes (changes to Feed in Tariff conditions)	Yes (Feed in Tariffs up to 500 kW)	Yes (changes to Feed in Tariff conditions)	-	-
Collective self-consumption and delocalized net-metering	yes	-	yes	-	-	-
Sustainable building requirements		-		Yes – mandatory solar/livings roofs on some buildings and car parks	-	-
BIPV incentives	Yes (ended October 2023)	-	Yes (ended October 2023à	-	-	-
Merchant PV facilitating measures				yes, guarantee fund for CPPA		yes, guarantee fund for CPPA

4.1 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 Pluriannual Energy Programme (PPE) still sets the target for French photovoltaic capacity at 20.1 GW in 2023 and at least 35.1 GW in 2028. In order to achieve these targets, a schedule of calls for tenders has been adopted, with around ten calls for tenders launched each year.

In 2023, the then French Prime Minister, Élisabeth Borne, presented a new plan to the National Council for Ecological Transition (CNTE), setting out revised targets for renewable energy and solar power deployment by 2030. The updated targets specified in the plan aim for France to achieve 48.1 GW of photovoltaic capacity by 2030 and 140 GW by 2050. However, the PPE has not been updated to reflect this.

Countries within the European Union (EU) were required to submit a draft National Energy and Climate Plan (NECP) as part of their obligations under the Regulation on the Governance of the Energy Union and Climate Action. This regulation mandates that each member state develop an integrated plan that outlines how they intend to achieve the EU's energy and climate targets for 2030.

The European Commission evaluates the draft NECPs and provides feedback to ensure that national plans are sufficiently ambitious and aligned with the overall EU objectives. The European Commission has assessed France’s draft updated NECP, submitted in November 2023: France's 2030 values submitted in the draft for GHG emissions and share of Renewable energy in gross final consumption are below the ones resulting from EU legislation. The French government took these recommendations into account when preparing their final updated NECPs, which were due by June 2024. However, due to the political situation and the sudden parliamentary elections, France submitted its final national energy-climate plan (NECP) to the European Commission on July 10, after the deadline. This plan includes a 2030 renewable energy target of 570 terawatt hours (TWh), accounting for 41.3% of final energy consumption. However, the EU requires at least 44%.

4.2 Direct support policies for PV installations

4.2.1 Open volume feed-in tariffs for BAPV

Feed-in tariffs and net-billing tariffs are segmented according to system size and vary each trimester, with the variation pegged to grid connection requests for previous trimesters. For overseas regions, the tariffs are adapted to regional irradiation levels. Tables 17 and 18 detail 4 th quarter 2023 tariff levels.

The October 2021 framework, (modified July 2022, February, July and December 2023) for feed in tariffs for systems up to 500 kW on buildings, greenhouses and parking canopies 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.

To be eligible, the system must meet several criteria. The system sale is with injection of all or the surplus (individual or collective self-consumption), its power must be ≤ 500 kWp. The installation must be on a building, shed or canopy (includes agricultural greenhouses, covered areas, use to house animals). The installer must be professionally qualified or certified;

The system's carbon footprint must be of less than 550 kg eqCO2/kWp for installations of more than 100 kWp (Simplified Carbon Evaluation carried out by an accredited certification body: Certisolis in France).

In 2023, 1 858 MW of systems accessing the FiT were commissioned.

Table 16 — Systems commissioned accessing the FiT in 2023 –Mainland France

Peak Power range	Power accessing FiT [MWp]
0 – 3 kW	188.9
3 kW–9 kW	544.6
9 kW–36 kW	81.5
36 kW–100 kW	159
100 kW–500 kW	884
Total	**1 858**

SOURCE: « Bilan du développement de projets » CRE, April 2024

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

Tariff category	Power of PV installation	Tariff Q4 2023* (EUR/MWh)
Continental France — building applied PV		
Ta (no self-consumption)	≤3 kW	173.5
Ta (no self-consumption)	3 kW to 9 kW	147.4
Tb (no self-consumption)	9 kW to 36 kW	138.2
Tb (no self-consumption)	36 kW to 100 kW	120.2
Tc (with or without self - consumption)	100 kW to 500 kW	120.8 x inflation coefficient

* Installations for which a complete request for connection was made between 01/11/23 and 31/01/24.

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

Tariff category	Power of PV installation	Tariff end of 2023 (EUR/MWh)
Overseas France — building applied PV		
Sample system in Guadeloupe	2 kW	207.8
Sample system in Corsica	8 kW	163
Sample system in Réunion	50 kW	144.9

Note: for exact tariffs, refer to CRE publications; there is also a time-based compensation for grid manager commanded disconnections.

4.2.2 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, application and separated between mainland/non-interconnected zones (ie islands). Contracts are contract for difference, allowing candidates to set a premium level (that, depending on market costs, could go below the market costs).

The competitive tenders for photovoltaic systems on buildings, parking canopies. In 2022, all the calls for tender proved to be significantly under-subscribed as electricity prices increased and self-consumption or PPA become more attractive. Since the increase in the benchmark remuneration ceiling in 2023, the situation has improved.

4.2.3 BIPV development measures

The feed in tariff framework published in October 2021 includes an investment bonus for systems up to 500 kW using one of 4 approved, certified BIPV products. The bonus could be combined with the partial self-consumption bonus and feed in tariffs/net billing. This feed in tariff framework is no longer available as of 08/10/2023.

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 kWp	0.238 EUR per Wp installed	0.133 EUR per Wp installed
100 kW to 250 kWp	0.235 EUR per Wp installed	0.128 EUR per Wp installed
250 kW to 500 kWp	0.233 EUR per Wp installed	0.125 EUR per Wp installed

The complete application for connection needed to be submitted before 6 October 2023, the landscape integration bonus will no longer be granted for a photovoltaic project after this date.

4.2.4 Merchant and corporate PV development measures

Corporate PPA's are increasingly attractive considering rising electricity prices and consumer awareness, however securing financing has meant that only major and financially extremely stable companies are able to buy in as off takers so far. Petitions from industry and alternative suppliers and a national working group led to the announcement of a guarantee fund carried by bpifrance from 2023 that would ease the difficulty of obtaining financing for greenfield systems selling in CPPA, operating as insurance in case of an off taker defaulting, however some sectors remain critical as it will not be available for small to medium buyers, or alternative electricity suppliers, essentially restricting the use to companies already in the market.

The PPA guarantee fund (GER fund) was set up in November of 2022 and endowed with 68 million euros. It can guarantee approximately 500 MW of capacity. Eligible buyers are industrial

companies based in France, with no strict size or turnover criteria, and with a flexible financial rating, however the minimum volume is 10 GWh/year.

The guarantee covers new photovoltaic and onshore wind power installations in mainland France that have not yet been commissioned. The cost of the guarantee, borne by the buyer, varies according to a number of factors, including the nature of the asset, the duration of the PPA and the buyer's credit rating.

If the buyer defaults, the producer can terminate the PPA after three unpaid invoices and trigger the guarantee, with bpifrance compensating the producer for 80% of the PPA price. The producer can then look for a new buyer and submit a new application for a new price. The first contract was announced in October 2023 between Bonduelle (food industry) and Arkolia for a 10.4 MW ground based photovoltaic system and a refence volume of 11.8 GWh/year over 20 years.

4.3 Self-consumption measures

Table 20: Summary of self-consumption regulations for small private PV systems in 2023

PV self-consumption	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.
	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. The winning candidates in a self-consumption tender implemented in 2022 have been selected and the results published in 2023. Winning candidates in the Self-Consumption Tender may consume the electricity they produce themselves or sell it to third parties (e.g. by selling it directly to a consumer or on the electricity markets) and will receive support in the form of a premium (remuneration supplement) for the energy injected and for the energy they consume themselves, the level of which is defined by the applicant in its bid. The remuneration is designed to encourage self-consumption rather than feed-in to the grid. 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
	Charges to finance Transmission,	Systems with total self-consumption pay no connection or annual grid access costs.

	Distribution grids & Renewable Levies	Systems in collective self-consumption systems pay grid connection costs and annual access fees.
Excess PV electricity	Revenues from excess PV electricity injected into the grid	Net-billing set by FiT (Q4 2023: 130, 78 or 120.8 x coeff EUR/MWh depending on system size), or by Tender specifications (FiT or wholesale market + premium) or by PPA (Power Purchase Agreement). Systems may sell into collective self-consumption before selling excess within FIT framework.
	Maximum timeframe for compensation of fluxes	For single consumers: 5 minutes; in virtual collective self-consumption metering timesteps are 30 minutes.
	Geographical compensation (virtual self-consumption or metering, use of the public or private grid)	Called “collective self-consumption” in France. Participation in a collective self-consumption operation is limited to 3 use cases: 1. Default case: PV installations and consumers located in the same building. This opens the possibility for the participation of medium voltage connected PV installations; 2. Extended case: PV installations and consumers connected to the low voltage grid within a distance of 2 km. The Minister responsible for energy may grant a derogation at the reasoned request of the legal entity of an extended collective self-consumption project, where all the participants "are located exclusively in one or more rural or peri-urban municipalities in mainland France". The distance separating the two furthest participants can then be extended to 10 km (instead of 2 km) from September 2023; 3. 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 cases, generators(s) and consumers(s) must be linked through a common legal entity. Compensation on a 30-minute time-step.
	Number of participants (individual or collective self-consumption)	Individual self-consumption limited to 1 participant. No limit in participant numbers for collective self-consumption, but there are generator capacity limits, the combined capacity of the generating facilities involved in the operation must not exceed 3 MW.
Other characteristics	Regulatory scheme duration	20 years for surplus (net-billing) sold in FiT, 10 years in Self-Consumption Tender. Collective self-consumption determined by private contract.
	Third party ownership accepted	Third party ownership is allowed but can be complex to manage.

	Grid codes and/or additional taxes/fees impacting the revenues of the prosumer	Grid connection fees for systems over 36 kVA. 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.
	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.
	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 limited to 500 kW on buildings for access to net-billing and lump-sum within FiT framework. Systems must be between 500 kW to 10 MW to access Tenders (it is possible in this context to have a generator sell directly to a consumer without the generator being a registered electricity supplier). 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.
	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).
	Additional features	Markets sales of surplus in the framework of Tenders require access to an Aggregator/Balancing Responsible Party. Collective self-consumption systems can now access FiT for excess production sales since October 2021. The number of virtual battery storage offers is increasing.

4.3.1 Net-billing feed-in tariff and lump sum for BAPV systems under 500 kW

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

Tariff category	Power of PV installation	Net-billing tariff (+ lump sum) Q4 2023 (EUR/MWh)
Continental France — building applied PV		
Pa (net-billing)	≤3 kW	130 (+0.37 EUR/W installed)
Pa (net-billing)	3 kW to 9 kW	130 (+ 0.28 EUR/W installed)
Pb (net-billing)	9 kW to 36 kW	78 (+ 0.20 EUR/W installed)
Pb (net-billing)	36 kW to 100 kW	78 (+ 0.10 EUR/W installed)
Tc (net-billing)	100 kW to 500 kW	120.8 x inflation coefficient (no lump sum)

4.3.2 Net-billing with feed-in premium

Winning candidates in Self-Consumption Tender (systems from 500 kW to 10 MW) receive a bonus on self-consumption at the tendered rate plus net-billing set by tender specifications (wholesale market + premium).

4.4 Collective self-consumption, community solar and similar measures

Consumption within a building, a 2 km, or exceptionally, a 10 or 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 2023, with a total of 26.8 MW (+ 14.4 MW since Q4 2022) across 305 projects, 4 265 consumers and 664 generators were involved, with most indicators roughly doubling over 2023 (as was the case in 2022).

Economic models for self-consumption systems remain uncertain in the long term, 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, even when consumption costs were high over 2022. In 2023, despite the reduction in module costs, decreasing consumption costs did not significantly improve business models. However, the growth in operation is an indication how other factors contribute to the attractivity of collective self-consumption.

4.4.1 Solar Community (Renewable energy or citizen energy communities)

In December, the much-awaited decree completing dispositions for renewable energy community (REC) or citizen energy community (CEC), specifies in particular the concepts of autonomy and geographical proximity, so France now has a framework for accelerating participative renewable energy projects led by local players. It distinguishes, as European law does, between renewable energy communities (RECs) and citizen energy communities (CECs), and sets out their operating and control procedures: conditions of autonomy, geographical proximity criteria (for RECs), procedures for leaving a community, compensation for network operators, etc.

A renewable energy community can produce, consume, store and sell renewable energy, and share the energy produced within it. A CEC has a broader scope: energy production, supply, consumption, aggregation, storage and sale of electricity. It can also provide its members with energy services (energy efficiency, recharging points, etc.).

This text complements the citizen investment movement that operates in standard generation and electricity sales frameworks (see chapter 3.5 Community solar (citizen investment)).

4.5 Tenders, auctions & similar schemes.

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.

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 became much higher (up to 8 times higher) than the tendered prices from late 2021 to early 2023, before dropping significantly in the second quarter of 2024. As a result, whilst the generators concerned saw revenues increase in this period from their sales on the market, a significant portion of this revenues was paid to the state under the CfD mechanism. Not only did the French state *not* subsidise these contracts for those months, but it also received a portion of the revenues generated by photovoltaics. However, prices on the electricity market have steadily decreased over 2023 coming back to a more habitual level close to the prices tendered.

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

The current framework (called PPE2) has selection criteria 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 anthropized sites are benefited), or even innovation levels, for larger systems.

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).

There were 7 national calls for tenders in mainland France over 2023, including a technology neutral tender and one tender in the overseas territories (ZNI).

4.5.1 Competitive tenders

Table 22: 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	Systems located in non interconnected areas (ZNI)	Technology neutral	Building mounted innovative solar systems	Ground based innovative solar systems
Individual system size limits	From 0.5 MW No upper limit	0,5 MW to 30 MW No upper limit on degraded sites	From 0,5 MW (Group 1) and from 0,5 MW to 12 MW		0,1 MW to 3 MW	0,5 MW to 3 MW
Volume	14 calls of 300 MW to 800 MW	10 calls of 700 MW to 1500 MW	11 calls of 40.5 MW and 58.8 MW	5 calls of 500 MW	5 calls of 80 MW	5 calls of 60 MW
Number of Bids	**4 th call:** 58 MW selected for 400 MW called **5 th call:** 342 MW selected for 800 MW called **6 th call*:** 362 MW selected for 400 MW called	**4 th call:** 1519 MW selected for 1500 MW called **5 th call*:** 912 MW selected for 925 MW called	**1 st call*:** 49.77 MW selected for 99 MW called	**2nd call:** 435.2 MW selected for 500 MW called	**1 st call:** 80.38 MW selected for 80 MW called	**1 st call:** 60.1 MW selected for 60 MW called
Average tendered price (or bonus for self-consumption)	**4 th call:** 104.52 EUR/MWh **5 th call:** 101.24 EUR/MWh **6 th call*:**	**4 th call:** 82.42 EUR/MWh **5 th call*:** 81.9 EUR/MWh	**1 st call *:** 89.52 EUR/MWh	**2nd call:** 84.8 EUR/MWh	**1 st call: **** 89.84 EUR/MWh	**1 st call: **** 73.96 EUR/MWh

	102.1 EUR/ MWh					

*These tenders were called in 2023, however, the results were published in 2024.

**called in 2021 and published November 2022.

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

4.6 Other utility-scale measures including, floating and agricultural PV

These systems are financed through competitive tenders, generally in a specific call for innovative systems. Agrivoltaic systems were defined in law as dual-purpose systems, using the same land for both solar energy production and agricultural activities. This approach integrates solar panels with farming practices, including growing crops, raising livestock, managing greenhouses, and supporting pollinators, to maximize land efficiency and productivity. Given the constraints, AgriPV systems are unlikely to be developed on the same scale as ground mounted systems on farmland. The eligibility conditions for the PV on Buildings competitive tender were modified to explicitly exclude canopies over livestock (reserved for over plants). Parking canopies are mandatory for certain car parks over 500 m^2 (new) 1500 m^2 (existing) and this is likely to become an important market segment in France for large scale systems, with systems eligible for the PV on Buildings Competitive Tenders.

In 2023, the floating photovoltaic sector in France experienced notable growth with significant projects highlighting the sector's potential. EDF Renewables commissioned its first floating solar plant in the country, a 20 MW facility located near a hydropower dam in Lazer, Provence-Alpes-Côte d'Azur. Floating PV projects in France are still at the early stages of their potential, the sector is just beginning to explore the extensive opportunities presented by this technology.

4.7 Indirect policy issues

4.7.1 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 MEUR budget in 2023, equivalent to the 2022 budget. 1.7 MEUR of credit payments were authorised although only 0.2 MEUR were executed. 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.

4.7.2 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 2023 about 345 storage facilities were connected to the medium-voltage grid with a capacity of 433 MW.

Individual/small scale storage: Conditions are not economically 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 are about 17 000 (12 000 mainland, + 5 000 overseas territories) storage facilities in France on residential or small-scale installations. After a peak of 2 500 new installations per year in 2018 and 2019, the rate of decrease through 2020 and 2021, but began to rise in 2022. In 2023, the number of installed storage systems reached a new high of almost 3 245 in Mainland France and 1 267 in non-interconnected zones (overseas territories and Corsica).

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.

The winter of 2021-2022 saw the highest electricity consumption in France for five years. The government ran a national campaign inciting user, commercial, industrial and residential, to reduce their consumption or move its timing to prevent brown outs. This campaign was successful (extremely high electricity prices were surely an additional motivation), a significant drop in electricity consumption was observed in the following winter, 2022-2023. This trend stabilised in the winter of 2023-2024.

On the Enedis perimeter, representing around 80% of French consumption, consumption (adjusted for climate and Covid effects) fell from 205.50 TWh in 2021-2022 to 192.17 TWh in 2022-2023, then to 192.38 TWh in 2023-2024. This 6.4% reduction in consumption compared with 2021-2022 is equivalent to the annual consumption of three million homes. The biggest reduction was seen among businesses, followed by households and professionals (small shops, billboards, public lighting). In percentage terms, professionals and businesses reduced their consumption by 8.2% and 7.2% respectively.

On a more local level, for the 4th consecutive year, Enedis, the operator of the public electricity distribution network, launched a call for tenders for local flexibility services, open from 13 March to 9 May 2023. It concerned 11 identified areas in 8 French departments, but with mixed success, Enedis selected 4 bids for 4 areas of opportunity.

4.7.3 CPPA/PPA market

There is a small but growing corporate PPA market in France, mostly lead by major companies such as SNCF (national railways), airports, and international corporations (Amazon etc). In France, the first corporate PPA (CPPA) for the purchase of electricity from renewable sources was announced in 2019. Since then, between 5 and 10 PPAs have been contracted each year. The year 2023 saw an acceleration in the number of announcements, and by the end of year, 43 CPPAs had been signed, including 1 multi-buyer contract. Of these 28 were solar greenfield systems. Contracts for greenfield systems run from 15 to 25 years, with an occasional contract announced for only 10 years. For systems moving away from feed in contracts, contracts tend to a 3-to-5-year limit. Corporate PPA's are increasingly attractive considering rising electricity prices

and consumer awareness, however securing financing has meant that only major and financially extremely stable companies were able to buy in so far. Petitions from industry and alternative suppliers and a national working group led to the announcement of a guarantee fund that would ease the difficulty of obtaining financing for greenfield systems selling in CPPA. However, some sectors remain critical as it will not be available for small to medium buyers, or alternative electricity suppliers, essentially restricting the use to companies already in the market.

4.7.4 Support for encouraging social acceptance of PV systems.

On a general level, solar enjoys a good level of social acceptance and approval level. The RTE Ipsos study on the decision-making mechanisms of the French population in terms of energy consumption, carried out in 2023, shows that the same proportion of the sample surveyed in 2022 have a good opinion of photovoltaics (66%). However, 16% have a bad opinion (compared with 18% in 2022). There are no major differences in opinion between age groups.

Social acceptance for utility scale projects in France has become a growing problem over the past years. Utility scale remains the biggest challenge with many projects being challenged. Their development requires land (between 0.8 and 1 ha to install 1 MW of photovoltaic panels), and land zoned for agricultural use has been used in the past – although it must be noted that more than half the surface of mainland France is reserved for some sort of agricultural use (including forestry and unused prairies). Protests against utility solar have tended to focus on environmental issues, including those relating to quality of life, such as changes to the landscape or the intensification of the transport of materials. The issue of preserving France's ability to feed itself has also been a strong motivator for authorities to actively frame the use of agricultural land for solar. Some agrivoltaic projects are in operation and they aim to ensure that the two activities coexist in a beneficial and complementary way.

In the last few years, industry worked on gathering information on the environmental impacts of utility scale systems, resulting in several publications. Against a backdrop of rapidly accelerating deployment of renewable energies (RE) and the renewal of licences or repowering of existing plants, combined with the massive decline in biodiversity and tensions between the stakeholders concerned, the French government has made it a priority to reconcile RE, biodiversity, soil, water and landscapes. To meet this priority, the French Office for Biodiversity (OFB) and ADEME have drawn up a joint roadmap. The multi-partner national observatory for "Renewable Energies, Biodiversity, Soil, Water and Landscapes", was included in the 2023 Law for the Acceleration of Renewable Energies.

The government also has supported the development of citizen investment as a tool to increase social acceptance.

4.8 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 2023 for photovoltaic contracts (Feed-in tariffs and premiums) for continental France is negative

81.3 M EUR, in other words a source of revenue for the state government. This number was first estimated in November 2022 to negative 2 744 M EUR, it was reevaluated in July of 2023 as electricity market prices dropped. The large gap between the two estimations is linked to the drop in costs in the PV sector. The definitive total cost will be known when the CRE publishes its deliberations on the evaluation of public service energy charges in July 2024.

4.9 Grid integration policies

4.9.1 Grid connection policies

In France grid connection costs are paid by generators, with total costs shared between an initial upfront payment by the generator directly proportional to costs and an annual access fees (TURPE).

The cost to the generator depends on:

- the works needed to connect the system to the grid, determined by the DSO and based on the existing grid capacity and infrastructure and the projects and works already in the grid connection queue;
- the cost of these works - part of these costs are based on a pre-established framework and part depends on the specific system and site and they cover modifications needed upstream on the grid;
- the distribution of costs between the generator and the DSO; this distribution depends on the nominal voltage of the grid connection.

Costs can be mutualised if several systems are grouped together and connected in the same time frame.

Connections to the medium voltage grid and impacts on the medium and high voltage grid include contributions to regional funds (Schéma Régional de Raccordement au Réseau des Energies Renouvelables (S3REnR)) that finance future grid upgrades that are planned according to projected renewables growth, allowing for mutualised contributions to infrastructure costs such as high voltage grid upgrades, new substations etc. The regional contribution is payable for systems connected at 250 kVA and up, and ranges from 0 to roughly 80 000 EUR/MW depending on the regions current grid capacity and infrastructure and projected growth of decentralised generation.

The upfront costs can be significant, affecting project feasibility at all power levels, from residential systems to utility scale ground-based systems. These costs and the cost sharing framework between generators and DSO is a recurring source of conflict with calls for more transparency on methods but also more agility in adjusting the S3REnR considering growth in renewables.

In the past, single phase grid connection costs for small residential systems were a real barrier to the development of the sector, however the shift to self-consumption, with its mostly zero-fee grid connection, has both lowered the overall cost of residential systems and accelerated the grid connection times. It is unlikely that grid connection capacity will be a barrier for increased development of small residential systems.

Currently, the cost of grid connection for small commercial systems up to about 1 MW is extremely variable and difficult for installers and building owners to predict, which means that grid connection studies and quotes must be made before generators or investors can validate business plans – mechanically adding months to project planning. High costs are generally the

direct consequence of older grid infrastructure or saturated substations, requiring the generator to assume the costs of infrastructure upgrades often benefitting both the generator but also consumers. Changes to the DSO (Enedis) standard method of determining transformer capacity in late 2023 are likely to free capacity for more solar to be connected without triggering upgrades, whilst since early 2023 small scale inverters must meet new parameter requirements, a move that Enedis estimates will allow to connect 30% more capacity without upgrades. The unpredictability of grid connection costs is a factor in the longer lead times for commissioning in France, and the abandon rate for projects across this segment. DSO efforts to improve visibility on grid connection costs in planning phases include establish grid capacity maps and automated web services to indicate the complexity of grid connection. Whilst these services do not supply all information, they are providing a first level of service that facilitates project planning.

Delays for grid connection are variable – from none for residential self-consumption systems up to a dozen years if TSO infrastructure is inadequate for a utility scale project. As a general rule, delays for most residential and commercial systems on the low voltage grid have delays from 3 months to about 18 months, whilst delays for connection to the medium voltage grid are dependent on local grid capacity and project works. Once a connection request has been validated, the connection proposal (PDR) specifies the indicative connection deadline from the date of your approval and, where applicable, the list of work to be carried out.

To manage connection requests for generation facilities in the same zone, RTE and the public distribution system operators use a capacity reservation system known as the "Queue (File d'Attente". RTE classifies connection requests with a view to prioritising them on a "first come, first served" basis. This can result in small projects wanting to connect to the low voltage grid being frozen out as larger projects immobilise all remaining capacity despite not being able to use the available capacity until upgrades on the medium or high voltage grid can be planned, often requiring several years to be completed.

With its strongly interlinked network, grid capacity in itself should not be a substantial barrier to the developments of photovoltaics per se, however aging rural infrastructure and the cost sharing model – with its impact on project viability - are not negligeable barriers, and the long lead time for increasing transport network capacity means that France's ambitious development goals may not be that easy to reach. Réseau de transport d'électricité (RTE) has published, in September 2023, a study on the French electricity system up to 2035. The operator of the French electricity system is fairly reassuring about France's ability to meet its sharply rising electricity needs, provided a faster deployment of renewable energies. In parallel, Enedis, the major DSO on mainland France, published a preliminary document to its "Network Development Plan" in March 2023. This preparatory report is intended to shed light on Enedis' growing investment trajectory up to 2027 and 2032, and to contribute to the debates surrounding the future Multiannual Energy Programme (PPE).

4.9.2 Grid access policies

Recurring grid access fees (Tarif d'Utilisation des Réseaux Publics d'Electricité – TURPE) are paid by all users with contributions calibrated to cover all of a DSO's operating and investments costs, including the cost of capital. Access costs are determined according to

- voltage level of the user grid connection;
- the type of user (consumer/generator);
- and for certain users, the time of use.

Unlike many other European countries, there is no geographical differentiation of tariffs.

The total cost of the TURPE is defined by the energy regulator (CRE), directly defining DSO's revenue for public service type missions. The energy regulator also defines the cost sharing between types of users, based on a study of the users' impact on the network and the costs they generate.

The fee structure is based on cost components and adapted to voltage level and type of user and the principal components for generators are:

- Annual management component (CG);
- Annual metering component (CC);
- Annual injection component (CI) – high voltage grid connections only;
- Connection point grouping component (CR);
- Annual component of reactive energy (CER);
- Public service contribution (CSPE).

Costs have a significant capacity base but include an energy cost. Whilst grid access costs are generally not a significant part of OPEX costs, this does vary depending on the type of injection and the different legal entities attached to a system and consumption points - access fees for self-consumption systems are significantly lower than full sales systems as several cost categories are mutualised with the consumer fees.

The fixed part of annual access fees range from approximately 10 EUR/year for self-consumption systems under 36kVA to approximate 500 EUR/year excluding VAT for systems under 250 kVA. For systems connected to the high voltage grid this as in the range of 800 EUR/year.

5 INDUSTRY

5.1 Production of ingots and wafers (crystalline silicon industry)

Table 23: Silicon feedstock, ingot and wafer producer's production information for 2023.

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

Photowatt (EDF ENR PWT) is a French wafer manufacturer and module supplier specialized in low carbon content solutions. It produces cast-mono silicon ingots, bricks and wafers (Crystal advanced process). In 2022, Photowatt was the first company in Europe to upgrade its production to the large format G12/210 mm. In 2023, Photowatt ordered some new slicing equipment to be implemented in mid-2024 to increase capacity to more than 200 MW.

ECM Technologies group, based in Grenoble and near Montpellier, focuses on supplying photovoltaic equipment manufacturing for the end-to-end value chain, from ingots to cells.

5.2 Production of photovoltaic cells and modules

Table 17: PV cell and module production and production capacity information for 2023

Cell/Module manufacturer	Technology (sc-Si, mc-Si, a-Si, CdTe, CIGS, OPV)	Production and/or capacity (MW/year)	
		Cell	Module
Wafer-based PV manufactures			
Voltec Solar	sc-Si		500 (capacity)
Reden Solar	sc-Si		65 to 200 (capacity)
Recom Technologies	sc-Si		100 (capacity)
Systovi	sc-Si		80 (capacity)
VMH Energies	sc-Si		0
S'tile	sc-Si		35 (capacity)
CréaWatt	sc-Si		/
Heliup	sc-Si		/
Thin film manufacturers			

ARMOR	OPV	5	5
Dracula Technologies	OPV	/	/
Solems SA	a-Si		/
SolarCloth	CIGS		/
Soy PV	CIGS		/
Others products			
AKUO Sunstyle	Sc-Si (PV tiles)	/	/
Edilians	Sc-Si (PV tiles)	/	/
Dualsun	PVT	/	/
Total			**Approximately 800 MW**

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

The national industry is relatively small, with several manufacturers targeting specific niche markets, often related to building integrated products (PV tiles, façade elements...), PV/thermal hybrid modules (Dualsun, Systovi...) or small-scale production runs and pre-industrial research (Photowatt...). This industry operates with strong public R&D/industry links. Manufacturers struggled in 2023 as module prices dropped significantly at the end of the year and Chinese imports grew, and several went into liquidation towards the end of 2023 or in 2024.

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

- **Voltec Solar** assembles modules on their Alsace site, its production capacity is 200 MW/year. A new production line is to be installed in early 2024 to reach a production capacity of 450 MW/year. Voltec, in partnership with IPVF, also announced its intention to launch the industrialisation of a 4T perovskite-silicon tandem technology developed in-house by IPVF, to reach a 200 MW industrial demonstrator in 2025;
- **Reden Solar** manufactures modules, but also develops and operates photovoltaic power plants. It's semi-automated and automated production lines manufacture modules. In addition to their existing 65 MW/year line, the company invested in a new halfcut-cell module production line with a capacity of 200 MW/year. It should start in early 2024. To consolidate Reden Solar's business development, Macquarie Asset Management, BCI and MEAG acquired Reden Solar for 2.5 billion EUR in 2022;
- **Recom Technologies**'s Lannion site production has a capacity around 100 MW/year. In November 2023, the company was placed in receivership;
- **Systovi** assembles monocrystalline modules. Its manufacturing facilities are located at Carquefou, close to Nantes. The company, owned by the Cetih group, invest in a new production line in 2023 with a capacity of 80 MW/year. It is also preparing for an optional expansion to 350 MW/year with the possibility of using heterojunction technology;

- **VMH Energies** production site is located in Châtellerault near Poitiers. Its production capacity was 60 MW per year. After ceasing production of conventional modules in France in 2022, VMH has also ceased production of special modules in 2023. Its activities have been refocused on the development of mobile and modular ground-mounted installations;
- **Sunpower (Total Group subsidiary)** closed its 2 plants in Moselle and Toulouse in 2022. The launch of production of a new ultra-thin elastic panel, announced for 2021, has finally been cancelled;
- **Creawatt**, based in Ambilly, is focusing on the production of lightweight modules that can be attached to the roof using a grip, in partnership with the Chinese group Sunman. These products are intended for logistics and supermarket roofs. For the time being, only the grip is being added in France. Creawatt has announced that it intends to bring a module production line back to France and is considering the development of a gigafactory based on this technology;
- The start-up **Heliup**, founded in 2022, assembles lightweight, durable modules with thin glass protection and no frame. Their ambition is to set up a 100 MW/year production line in Le Cheylas (Isère) by 2024.

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

- **S'Tile** uses the technology known as i-cells, bi-glass and bifacial modules. Their modules are either integrated into buildings or integrated into off-grid systems. Over 2022 they have been active in repowering, replacing modules on damaged systems. This last activity accounted for half of their business in 2023. They develop made-to-measure photovoltaic modules, with annual production varying between 25 and 50 MW. Around 70% of their production is sent to Europe, with only 30% of modules destined for French installations;
- **ARMOR** developed and manufactured proprietary organic "ASCA" films under the ASCA brand with part of the manufacturing process in France before products are finished in Germany. The products target the market for connected devices, wearable photovoltaics as well as building integration applications (semi-transparent glazing...). The German construction group HERING bought ASCA in 2023;
- **Dracula Technologies** is a start-up developing printed organic photovoltaic cells (trademarked LAYER technology) aimed at the connected device market. Their cells capture ambient light, whether natural or artificial. Their modules have a standard surface area of 42 cm^2 and deliver a standard micro-power of 7.5 MW. Its pilot line was inaugurated in September 2019 and its "Green Micropower" Factory became operational in January 2024, and announces it is "ready to scale to 150 million cm^2 of printed surface per year" up from 5 million cm^2/year in 2023;
- **Solems SA** manufactures thin-film elements and modules up to 30 cm x 900 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 (VIPV). They supplied products used in the Paris Olympic precinct. With **Soy PV**, SolarCloth has launched in 2023 an R&D project with a pilot demonstrator for an industrial sector, with the aim of going to commercial scale and producing 30 MW/year by 2030;
- **Edilians**, manufacture PV tiles (previously eligible for the BIPV bonus in the feed in tarif, that stops in October 2023; they also put a red tile on market);

- **DualSun** develops and markets photovoltaic-thermal hybrid modules (PV-T). The photovoltaic part is manufactured in China, then the thermal part is added in French factories.

5.3 Manufacturing Projects

In 2023 there were two major manufacturing projects in France: Holosolis and Carbon.

Holosolis, a consortium including EIT InnoEnergy, IDEC (a French property developer) and TSE (a utility scale and agrivoltaic developer), has planned factory on the site previously abandoned by a REC project. Production is due to start in 2025, rising to 5 GW/year from 2027;

Carbon, a start-up with local industry backing aims to build an integrated plant producing 5 GW/year of cells and 3.5 GW/year of modules. The company has announced its intention to start production in 2025 at a site in Fos-sur-Mer near Marseille.

5.4 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 (many manufacturers anticipating new mandatory solar on car parks but also the uptake of electric vehicles…).

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. A number of manufacturers of solar support buildings (agricultural hangars, greenhouses) are also present (Mecosun…).

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

5.5 **Recycling**

PV is collected for recycling by SOREN in France under the WEEE national legislation. There were 461 sellers subscribing to SOREN in 2023, responsible for putting 5.9 MW of modules on the market (14.5 million modules/330 000 tonnes). 5 200 tonnes was collected, of which 90,5% was sent for recycling (less than 100 MW).

6 PV IN THE ECONOMY

6.1 Labour places

Table 25: Estimated PV-related full-time labour places

	Number of full-time (FTE) labour places	
Market category	**2019**	**2022**
Research and development (not including companies)	500	
Manufacturing of products throughout the PV value chain from feedstock to systems, including company R&D	700	2 300
Distributors of PV products and installations	5 100	27 000
Other	3 300	2 900
Total	**9 600**	**32 200**

Sources: Évaluation et analyse de la contribution des EnR à l'économie de la France et des territoires 2020, SER, and Becquerel Institute France estimates. *Etude ADEME "Marchés et emplois concourant à la transition énergétique" (2022), ** Solar Power Europe.

While jobs related to the manufacture of photovoltaic equipment dropped over 2023, those dedicated to installation and project development, studies and operations continue to grow. The rapid growth of the sector, and the lack of qualified manpower, has led to continued tensions in recruitment since 2021. A review of job adds by the Brawo recruitment agency over the 2nd semester revealed over 17 000 job offers within photovoltaics open (and it is assuming slightly higher volumes in Q3 and Q4). With the growth in the residential market, major installers also launched ambitious recruitment programmes to cover jobs across the spectrum from design to installation, as, for example, France Solar with a planned 100 recruitments. Qualit'ENR, one of the organisations qualified to certify installers eligible for Feed in tariffs had 2 800 certified installers (up from 1 470 end 2022) working in the residential and small commercial segments by the end of 2023 and a further 470 qualified to work on systems up to 500kWp – additionally, over 6000 professionals undertook training with them in 2023 (up from about 4000 in 2022). Developers also had significant plans (Boralex, 80 requirements in 2023), building on the dynamic 2022 year.

The most recent Renewable Energy Market and Employment Study was published in September 2022 and covers 2020 direct employment data. Industry body Solar Power Europe's "EU Solar Jobs Report 2022" published in September estimates that there are 33 000 FTE in France in 2021.

6.2 Business value

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 2023 (below) has been estimated based on 2023 trending prices and rectified 2023 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. The following table represents the value of investments in commissioned PV systems, and not the value of the market itself that includes future systems, services, research and other sectors.

Table 26: Estimation of the value of the PV business in 2023 (VAT is excluded)

Sub-market	Capacity installed in 2023 [MW DC]*	Average price with VAT [EUR/W]	Average price without VAT [EUR/W]	Estimated value M EUR
Off-grid				
Residential < 3 kW	290	2.6	2.36	685
Residential < 9 kW	651	2.5	2.08	1 356
Commercial < 100 kW	573	1.2	1	573
Commercial < 250 kW	961	0.8	0.67	641
Industrial > 250 kW	112	0.9	0.75	84
Grid-connected distributed	2587	1.55	1.29	3 340
Grid-connected centralised	1374	0.8	0.67	916
Estimated Value of PV investments in 2023				**4 000 to 4 500****

SOURCE: SDES, Enedis, BI France.

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

7 INTEREST FROM ELECTRICITY STAKEHOLDERS

7.1 Structure of the electricity system

With a highly concentrated electricity the 100% state owned EDF 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 23% of the share capital) and public distribution networks, which are owned by the municipalities (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.

7.2 Interest from electricity utility businesses

In France the only private electricity utility is EDF (fully owned by the State as of June 2023 after a buyback of remaining stock in 2022), 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) and Agregio (electricity aggregation for the market) are all active in France. 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 installed capacity of 117.3 GW and an installed renewable capacity of 47 GW gross worldwide at end-2023.

ENGIE is a gas utility also present in the development and generation of electricity capacity and has a solar portfolio of 6.9 GW installed and 2.2 GW under construction worldwide.

7.3 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.

8 PROSPECTS

As electricity market prices drop, the immediate economic attractivity of photovoltaics has diminished somewhat – however, consumers continue to invest to hedge against future volatility. The continued and significant drop in module prices internationally and in France that began in 2023 will continue well into 2025 and perhaps 2026 as market demand realigns with the increased manufacturing capacity coming from China. The impact of mandatory solar on car parks and in new and renovated buildings should begin to be visible by 2025 as permitting lead times can be long in France. All indications point to record volumes to be installed in 2024 as these factors combine to stimulate the local market.