APPLICATION NOTE
MEDIUM SIZE PV PLANT

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CONTENTS

SUMMARY

This Application provides an overview of the most relevant characteristics and considerations regarding commercial and tertiary sector Photovoltaic (PV) power plants (100 kW to 2 MW). It is aimed at potential investors (including industrial and tertiary sector companies, communities and financial institutions, among other parties). The objective of this paper is to fill the gap between very basic generalist papers and exceedingly technical analyses.

Over the past decade, the competitiveness of PV as opposed to other electricity sources has improved considerably, mainly driven by new technological improvements and cost reductions per unit of installed power. In many situations, PV systems represent a profitable and relatively low risk investment opportunity. Nevertheless, a case-by-case analysis should be performed to properly evaluate each project.

The principal technological choices to be made during a PV plant development project concern the actual PV panels, the mounting structures, the inverter, and the storage system. Relatively few major types of systems are currently available on the market for each of these components. This Application Note describes their main advantages and disadvantages. It also provides a comprehensive overview of the difficulties and risks that can be encountered during the PV plant development process.

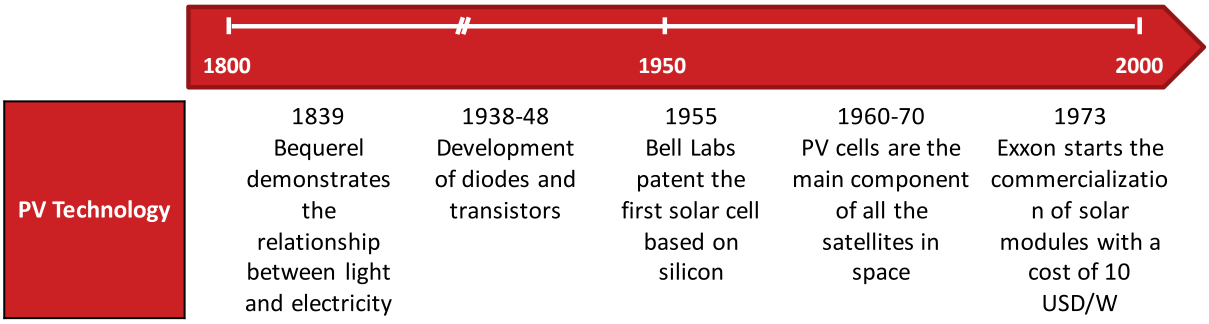
The business model of the project will primarily be determined by the local system of government incentives. This Application Note depicts key issues related to financing and the economics of a PV investment. It describes the choice between a corporate loan and a leasing formula and the calculation of the Internal Rate of Return (IRR). Finally, it executes a sensitivity analysis on the Levelized Cost of Energy (LCOE) of the PV plant. The cost of the EPC contractor and the local irradiation level turn out to be major parameters influencing the result. The discount rate and the lifetime of the PV plants influence the LCOE to a lesser extent. Note that the LCOE needs to be compared with retail electricity prices for residential PV projects, with commercial electricity rates before VAT for company PV projects, and with the cost of other electricity generation sources (e.g. a gas fired combined cycle plant) for electrical utility PV projects.

INTRODUCTION

It should be noted that this report only relates to medium size PV plants. Addressing the utility-scale PV sector requires a different approach than the one applied herein. It should also be noted that only ground-mounted PV installations are studied in the economic analysis.

A BIT OF CONTEXT

PV systems use the energy of sunlight to generate electricity. PV cells, the most important elements of these installations, convert the sun's energy into electricity through the photovoltaic effect, discovered by French physicist Antoine-Cesar Becquerel in 1839.

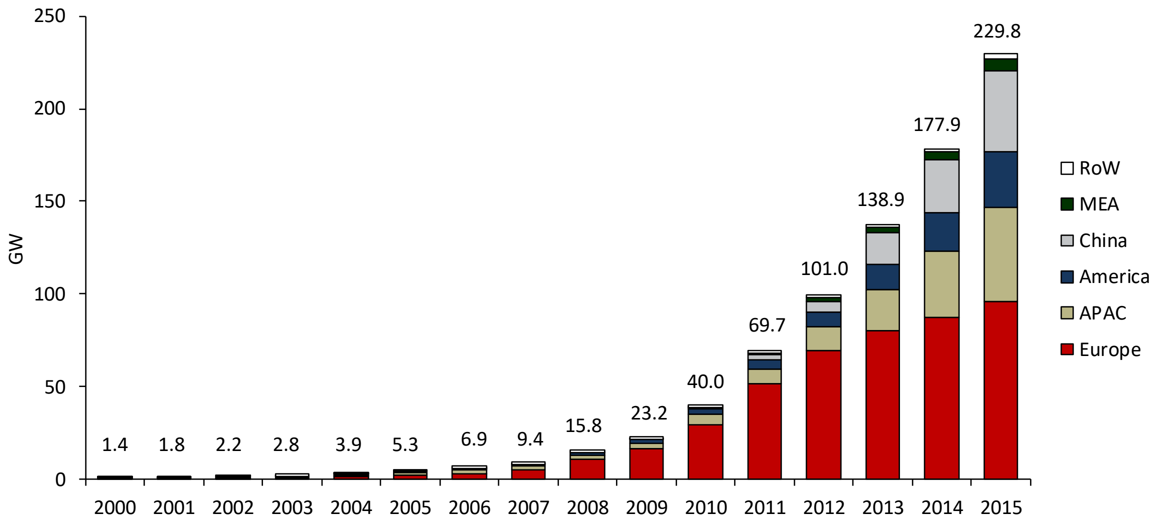


Source: CREARA analysis; *Club Español de la Energía*, June 2012

Figure 1–Main historical events of PV technology 1800-2000.

The market experienced a genuine paradigm shift between 2005 and 2015 because of the generous subsidies and incentive policies which have now been reduced in recent years. The significant growth of the global PV market has generated economies of scale, added to constant technological improvements and demand/supply imbalances that have led to a major decrease in PV prices.

The preliminary results from Solar Power Europe (EPIA) show that in 2000, the global cumulative PV installed capacity amounted to less than 2 GW. As of the end of 2015, capacity now exceeds 200 GW, as illustrated in the following Figure:

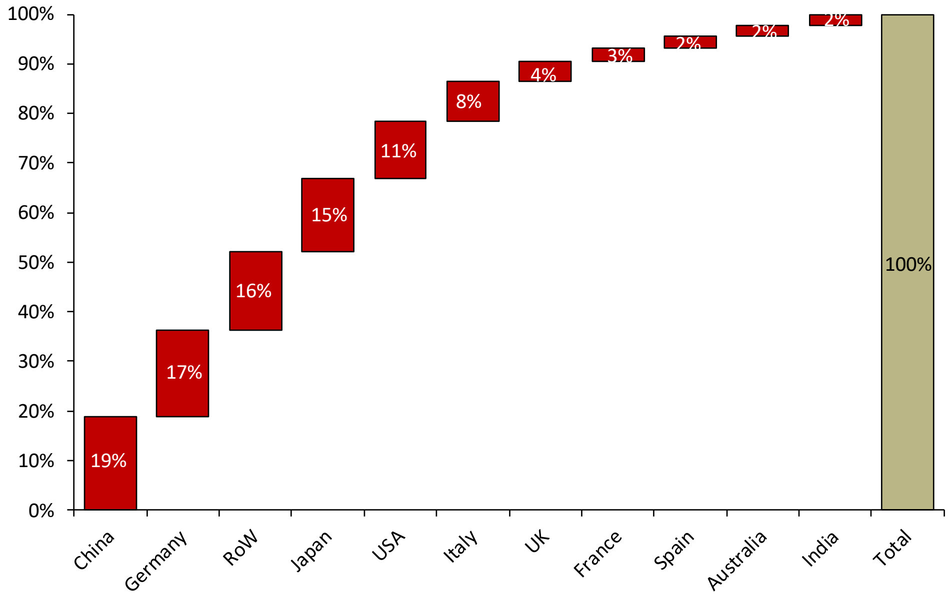


Note: ROW: Rest of the World; MEA: Middle East and Africa; APAC: Asia Pacific

Source: Solar Power Europe Global Market Outlook for Photovoltaics until 2020, Solar Power Europe Market Report 2016; CREARA Analysis

Figure 2—Evolution of global cumulative PV installed capacity 2000-2015.

It is important to note that new PV installations are now less Eurocentric than was previously the case. Europe´s share in the annual installed PV capacity reached 80% in 2010, then fell to 74% in 2011, and dropped down to 16% in 2015. Conversely, more than 30% of newly installed annual Solar system capacity has occurred in China (15 GW), a clear leader of the PV market. Overall, more than 36% of the type of PV installations being discussed in this paper is located in China and Germany. Figure 3 shows the location of the total installed capacity as of 2016.



Note: ROW: Rest of the World

Source: Solar Power Europe Global Market Outlook for Photovoltaics until 2020, Solar Power Europe Market Report 2016; CREARA Analysis

Figure 3–Global Cumulative Capacity as of 2016 segmented by market

Of the above capacity, utility-scale PV systems account for the great majority (67%), while in 2014 distributed solar and utility-scale PV installations had nearly equal shares. It is expected that in the future the share of utility-scale PV installations within total PV capacity will continue its lead as demand growth comes mainly from emerging markets where utility-scale PV is currently the preferred application.

Why PV?

PV systems have a number of unique and attractive advantages over other technologies. The merits of PV systems include the following:

- PV systems can potentially provide reasonable and **steady returns** with low correlation to financial markets at a relatively low risk[1].
- PV is a relatively mature technology in comparison to other renewable energy sources, **brilliant in its simplicity**. Sunlight is universally available, free, and can easily be predicted. PV systems have few moving parts thus require little maintenance.

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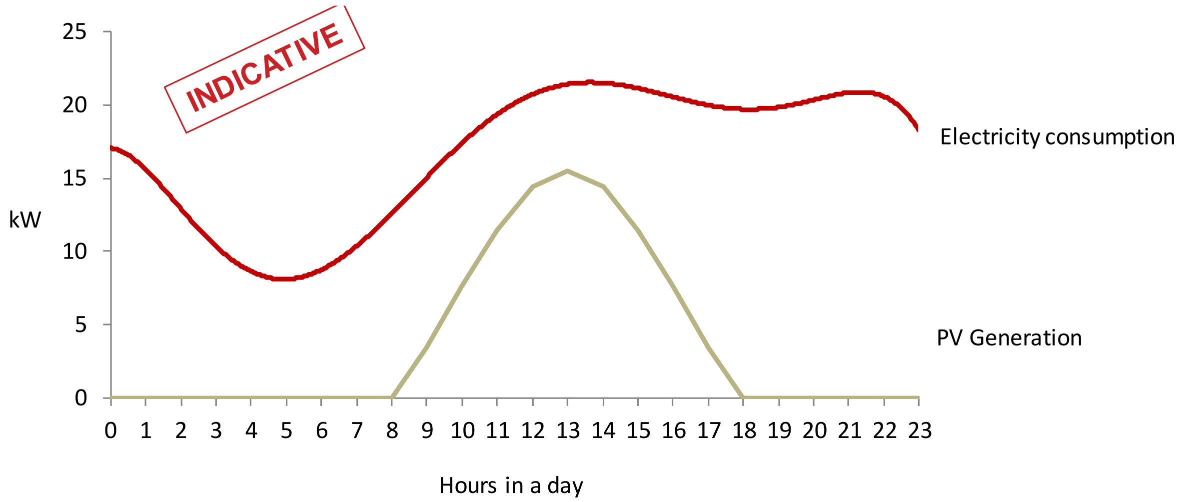
[1] The risks (legal, technical, financial, et cetera) can be measured, anticipated and mitigated by selecting an appropriate project developer.

- Investments in **environmentally friendly** energy sources such as PV are also governed by other non-economic motivations such as environmental sustainability, social responsibility, energy security, et cetera.
- By investing in a PV system, investors can hedge against rising prices of electricity from the utility, **eliminating future price uncertainty**.
- In many cases, a **good match between PV generation and electricity consumption** can be achieved, enabling 100% of instant self-consumption. Such PV systems can achieve economic feasibility even without any net metering/net billing or equivalent mechanisms. This case is illustrated in Figure 4.



Source: CREARA analysis

Figure 4—Illustration of PV self-consumption: daily electricity consumption and PV generation (500kW PV system).

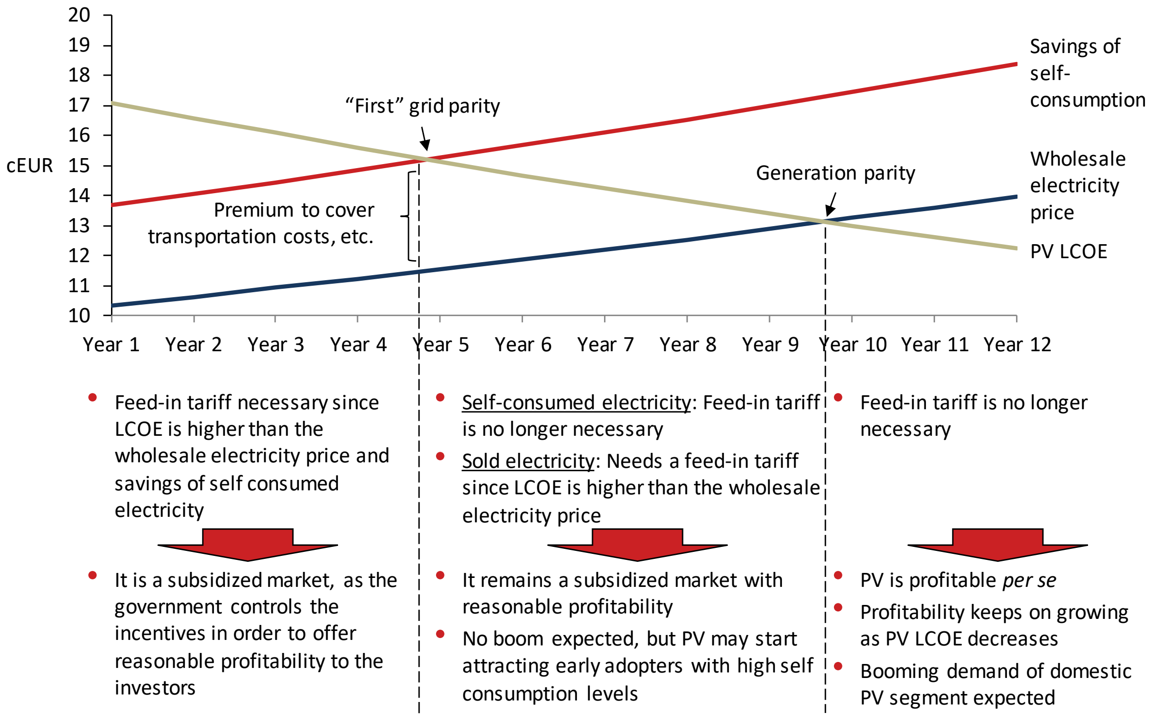
Government Incentives and Business Models

The PV market is likely to remain a subsidized market until generation parity[2] is reached. Currently, the significant improvement of PV cost-competitiveness can—in certain markets—be profitable *per se* (i.e., without any governmental support). In many cases, such as Chile, Mexico and Australia, it is already more beneficial for some electricity consumers to self-consume PV generated electricity rather than buy it from the electricity grid.

This relatively recent phenomenon coincided with the gradual elimination of public incentives such as Feed-in Tariff (FiT) schemes, and with the introduction of new business models based on market principles, such as those based on Power Purchase Agreements (PPA).

However, it should be noted that regulatory support could have a significant effect on the business model and profitability of the PV system. For instance, even if PV technology is competitive with grid electricity prices, the self-consumption market will fail to develop without governmental support (e.g. Spain).

As expected, business models have evolved in line with the stage of maturity of the technology in each particular market. Figure 5 illustrates the evolution of PV costs[3] and grid electricity costs and briefly explains the different support schemes according to the stage of development (i.e. 'first' grid parity and generation parity).



Source: CREARA analysis

Figure 5—Illustration of 'First' Grid Parity and 'Generation Parity'.

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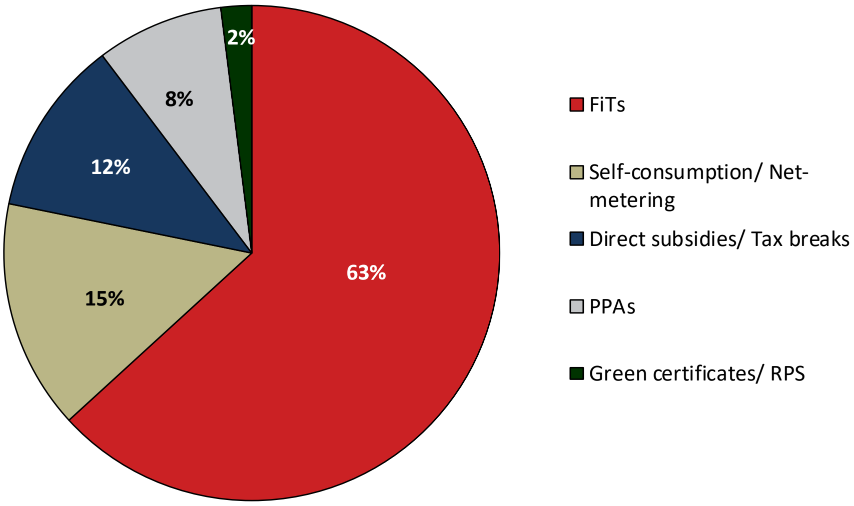
[2] Generation parity is defined as the moment when the wholesale price of electricity from the grid is equal to the cost of generating PV electricity.

[3] PV costs are expressed through LCOE (Levelized Cost of Electricity).

This section aims at providing an understanding of the main business models for PV systems, from those applicable in less mature markets to those in more mature markets. These include among others, FiTs, Self-consumption, Direct Subsidies and Tax Breaks, Power Purchase Agreements (PPAs), Green Certificates, RPS based systems, and Tenders. In 2015, less than 50% of solar power demand was driven by schemes other than traditional FiTs, as shown in Figure 6.



Source: Solar Power Europe Global Market Outlook for Photovoltaics until 2020; CREARA Analysis

Figure 6–Principal government incentives and business models for solar PV in 2015.

Feed in Tariffs (FITs)

FiT schemes effectively encourage the uptake of PV systems and can be found in markets such as France, Germany, Austria and the UK. However many countries in recent years have significantly reduced or even removed these fees. The main characteristics of this business model are as follows:

- It guarantees a fixed-price[4] contract for a specified long-term period and assures the purchase of all PV-generated electricity.
  - Another variant is based on a premium over the wholesale market rate, payment that can have a cap and floor.
- FiTs are generally designed to decrease over time as PV competitiveness improves.
- Tariffs can vary depending on the size, the geographic location and the type of system (e.g. Building Integrated Photovoltaics (BIPV) or Building-Applied Photovoltaics (BAPV) versus ground installations).
- The FiT can remunerate 100% of the PV-generated electricity, only the exported PV electricity, or both but with an additional premium to exported electricity.
- Overall, FiTs are relatively simple to implement and are effective in the short run. However, it remains difficult to set an adequate and updated rate for each renewable technology.

[4] This Price can be index-linked and decrease over time.

Self-consumption

- When PV becomes competitive with grid electricity prices, electricity consumers are better off by self-consuming PV-generated electricity rather than purchasing electricity from the grid. Indeed, the cost of PV self-consumption will be more stable than that of grid electricity. The primary reasons for choosing self-consumption over electricity tariffs are as follows:
    - Self-consuming electricity allows consumers to be less dependent on electricity distributors and retailers.
    - PV generated electricity presents a stable cost throughout the lifetime of the PV system while grid electricity costs vary over time.
- There are different business models available for self-consumption:
    - Net metering: a simple billing arrangement that ensures consumers who operate PV systems receive one-for-one credit for any electricity their systems generate in excess of the amount consumed on-site within a billing period. Under net-metering, every kWh of PV generation is equally valorized.
    - Net-billing: an arrangement by which the consumer receives one-for-one monetary credits for every kWh of excess PV generation they inject into the grid. Every kWh is valorized at its corresponding price, depending upon when it was exported. It is equivalent to a net-metering scheme but with monetary compensation instead of energy compensation.

Direct Subsidies and Tax breaks

- Direct subsidies are present in many markets, including Austria, Belgium, UK and USA, and are used to reduce the investment cost and the generation cost per kWh.
- The different categories of tax breaks oriented to PV energy are deductions (Belgium, United Kingdom, South Africa), tax holidays (India, Philippines) or accelerated depreciation (Argentina, Mexico, Netherlands, Peru), among others.
- Investment Tax Credits (ITCs) are tax related incentives that help to reduce the tax liability for purchasing qualified solar PV technologies. The existence of long-term multi-year ITCs encourage investment in PV projects.
- Overall, these measures are more effective when combined with other financial incentives.

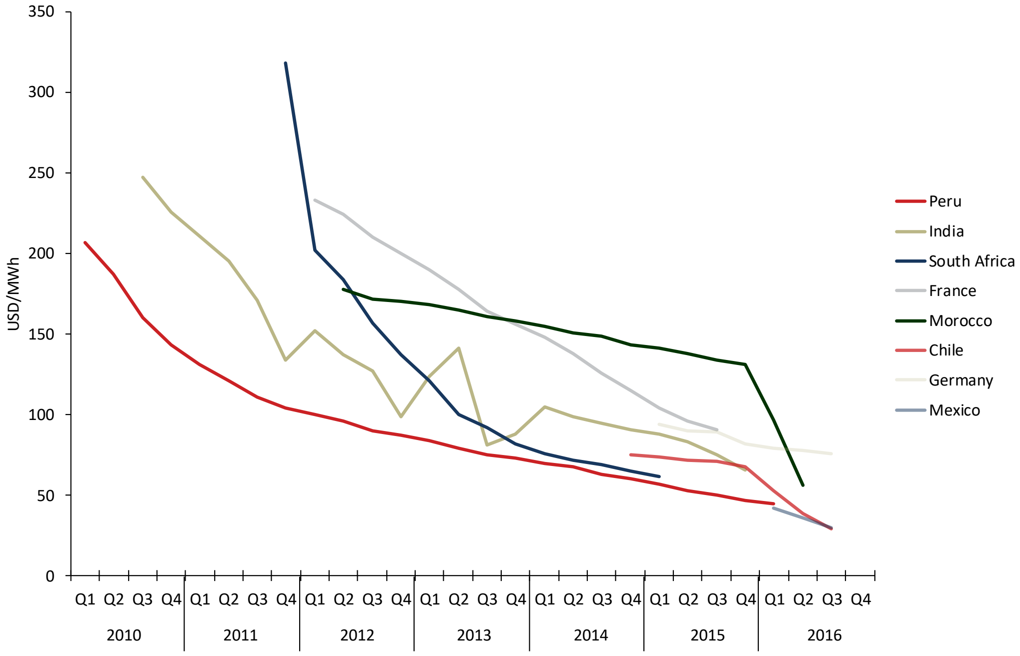
Power Purchase Agreement (PPA)

- A PPA is a long-term arrangement in which a developer installs and owns a PV system and then sells the PV energy back to the consumer at a set rate.
- As a result, the owner of the property will receive a constant and stable income while the electricity consumer can hedge against grid electricity prices by fixing the price of electricity for a long-term period.
- PPA price offers have declined in most countries in recent years:
    - Jordan: 120 USD/MWh in 2012 to 60–80 USD/MWh in 2015.
    - South Africa: 100 USD/MWh in 2014 to 65 USD/MWh in 2016.
    - India 110 USD/MWh in 2014 to 65 USD/MWh in 2016.
    - Chile: 90 USD/MWh in 2014 to 65 USD/MWh in 2016.
    - Germany: 100 USD/MWh in 2015 to 85 USD/MWh in 2016.

<u>Green Certificates/Renewable Portfolio Standards (RPS) and Tenders</u>

- Quota system (Green certificates/RPS): In some countries, energy suppliers are obliged to annually inject a minimum amount of PV electricity into the power system (US, UK, China and Germany). PV generators receive one Renewable Energy Certificate (REC) for each MWh of PV-generated electricity. These certificates can then be sold freely to energy suppliers. The downside of RECs is that their price is not fixed, and so project cash flows can become difficult to predict.

- Tenders: In recent years, auctions in PV have become popular among policy-makers in order to maintain a stable long-term environment for investors. In fact, some countries such as Canada or Germany are replacing FiT schemes with renewable energy auctions that reach high numbers of participants.



Source: "*Renewable Energy Auctions*", IRENA; CREARA research; CREARA analysis

Figure 7–Average solar prices in auctions, 2010-2016.

Equipment

This Section provides an overview of the essential equipment required within a PV system. These include PV modules, mounting systems, and inverters. A description of the available storage technologies is also provided.

Modules

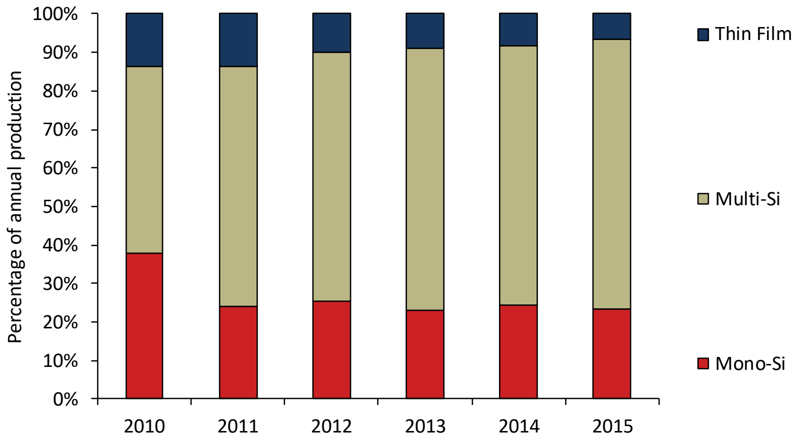
The PV industry is extremely dynamic and innovative, but the different technologies may be clustered into four major groups:

	Crystalline Silicon (c-Si)	Rigid Thin Film (TF)	Flexible Thin Film (TF)	Concentration PV (CPV)
				
Description	• Most commonly used ones, often described as high-cost, high-efficiency cells	• Semiconductor elements are deposited on thin film	• Similar to rigid TF but engineered onto flexible sheets	• CPV cells rely on the high concentration of light on 3 layer cells, boosting efficiency dramatically
Types (technologies)	• 1st generation: - Mono c-Si - Poly c-Si - Ribbon c-Si	• 2nd generation: - CIS[1] / CIGS[2] - CdTe[3] - a/µ-Si[4]	• 2nd generation: - CIGS - a-Si (3x)[5] • 3rd generation: - Dye-sensitized	• High purity Si and use of other materials: - Low: 2-10 suns - Medium: 10-100 suns - High: 200-1000 suns • III-V junction cells
Cell Efficiency (on site)	15-25%	7-14%	2-13%	30-45%
Costs (2016)*	50-70 cEu/W	30-50 cEu/W	40-55 cEu/W	80-100 cEu/W
Stage of Development	Mature	Mature	Moderate	Immature
Suitable Structures	• All types	• All types except for trackers	• BIPV, sloped and flat roof	• Double axis trackers

Note: 1) Copper indium diselenide; 2) Copper indium gallium diselenide; 3) Cadmium telluride; 4) Amorphous / micro-amorphous silicon; 5) Amorphous silicon triple union; * German spot market prices
Source: CREARA Research; CREARA Analysis; CREARA Interviews; PHOTON

Figure 8–PV Technologies.

The relative high efficiency compared to its cost makes C-Si the dominant PV technology, being used for over 90% of PV installations. This in spite of the fact that thin film technology has seen steady improvements as well, beating several efficiency records over the last year. On the other hand, it is estimated that CPV's share of the market will grow rapidly but will remain a minor segment.



Source: "*Photovoltaics Report*", Fraunhofer ISE, CREARA Analysis

Figure 9–PV Segmentation by technology type.

The PV module can be affected by the following factors during its lifetime:

- Mechanical loading caused by wind or snow.
- Contamination from pollen, dust, minerals and particles, which affects the clarity of the surface and lower the level of solar radiation that reaches the PV system.
- Moisture infiltration due to high humidity.
- Lack of ventilation (a minimum gap between modules is required to allow airflow and cool the PV system).
- Formation of hotspots where a shaded cell uses current from other cells, then converts into heat, damaging cell material, encapsulation and back sheet.
- Thermal expansion cracks due to extreme temperatures in winter and summer as well as rapid thermal cycling of sun and passing clouds.
- Yellowing (yellow coloration of the cell encapsulation), which produces cell bleaching, bubble formation, cell corrosion and higher heat absorption.
- Micro cracks in production, transportation and installation phases.
- Loss of efficiency and performance over the lifetime.

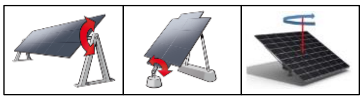
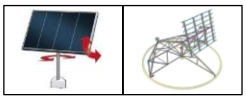
Module manufacturers usually guarantee their product for a period of 10-12 years. This can be extended for an additional premium. In addition, PV module performance is guaranteed for 25 years.

In this sense, the industrial standards are that, after 10 years, the output power shall not be less than 90% of the minimum output power set in the specification and after 25 years, this percentage shall not be lower than 80%. However, a case-by-case review of the specific offering by PV manufacturers is necessary when deciding between alternatives.

MOUNTED PV SYSTEMS

Mounted PV systems include ground-mounting and roof-mounting. Given that a roof-mounted PV system is generally small-scale[5], for the sake of simplicity the present paper will focus on ground-mounted PV installations.

There are three main categories of ground-mounted systems for PV installations. These are illustrated in Figure 10.

	Fixed mounted systems	Single-axis tracking systems	Double-axis tracking systems
Description	 • Fixed structure that does not follow the sun's trajectory • Mechanical simplicity • Lowest installation / O&M cost	 • Tracks sun with a single pivot point • Lower cost and maintenance compared to dual-axis	 • Tracks sun from east-west and north-south using two pivot points • Complex design due to more motors and sensors
Yield increase[1]	Not applicable	Up to 25% - 30%	Up to 35% - 45%
Price range[2]	5 – 20 EUR ct / Wp	15 – 25 EUR ct / Wp	45 – 70 EUR ct / Wp
Types		• Horizontal • Vertical • Tilted	• Tip-tilt • Azimuthal-altitude

Note: [1] Increase of production yield of installation with respect to fixed mounting systems, yield ranges indicate supplier sales information;
[2] Turnkey price, including structure supply and mechanical mounting (structure + modules)

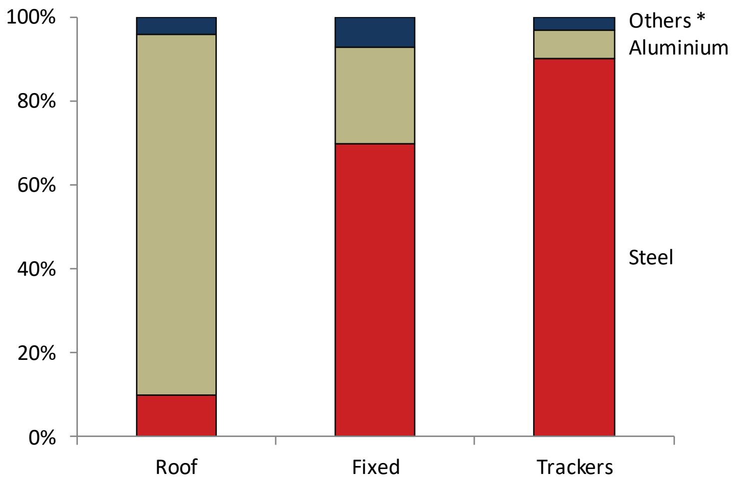
Source: CREARA research; CREARA interviews

Figure 10—Ground-mounted systems for PV installations.

Of these, fixed mounted systems are the most common, since tracking systems are only cost-effective where there is very high solar irradiation. Single-axis trackers are the norm. Double-axis trackers represent only a minor and declining share of the market. Double-axis trackers are currently a non-competitive product due to their higher costs, their higher complexity and the significant cost reduction experienced by PV technology in recent years that has generally not been matched by double-axis trackers.

In terms of the materials used, rooftop mounted systems are mainly made of aluminum, while fixed PV systems can be made of steel or aluminum, and trackers are generally made of steel.

[5] Most of the roof-mounted systems range from 1 to 100 kW; flat roofs are the only exception, as these systems can range between 50 to 500 kW and have been known to reach more than 1MW when placed on industrial roofs.



Note: * Mainly steel for nuts and bolts
Source: ECLAREON Analysis; ECLAREON Interviews

Figure 11—Main materials used in PV Mounted Systems (Europe).

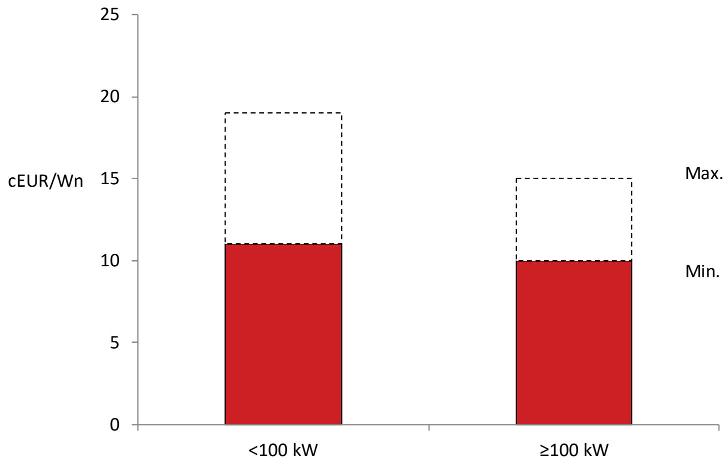
Typical guarantees for PV mounted systems last for 10-15 years. Extended guarantee can be obtained of up to 25-30 years, usually to address specific corrosion problems.

The principal potential problems of PV mounting systems are as following:

- Mechanical loading caused by wind or snow
- Corrosion, in particular for those PV systems in highly corrosive environments (salt air locations, for instance), where anti-corrosion properties become more relevant
- Trackers can suffer mechanical problems that increase down time

INVERTER

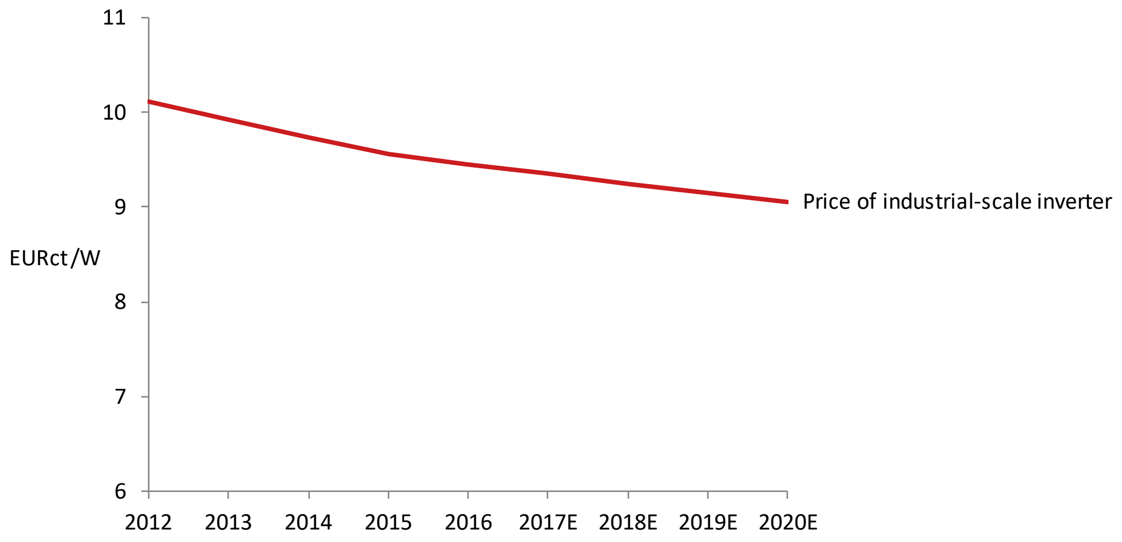
The inverter transforms direct current (DC) electricity generated by the PV system into alternating current (AC) electricity. As Figure 12 shows, there are significant price differences for the same inverter types: the smaller the inverter, the larger the range of prices.



Source: "*Photovoltaics Report*" Fraunhofer ISE; CREARA research; CREARA analysis

Figure 12—PV inverter retail prices.

The future evolution of these prices was calculated considering the current prices in a mature market such as Germany and a 10% learning factor, as well as future inverter production volumes (on the basis of EPIA projections on global PV installed capacity). As shown in Figure 13, it is estimated that from 2012 to 2020, inverter prices will decrease an average of 3% per year.



Source: CREARA analysis

Figure 13—Learning Curve Projection of PV Inverter Price 2012-2020.

Typical guarantees for PV inverters range from 3 to 10 years whereas warranties can be extended up to 25 years. Most common guarantees and warranties of PV inverters are shown in the following Table.

	Main Characteristics
Availability guarantee	• The performance of the inverter is guaranteed for a minimum number of days per year (expressed in %) in exchange for a fee. • In case this percentage is not met, the manufacturer pays the client a compensation by day and W of the inverter.
Warranty	• Warranties up to 20-25 years are valued by the client. • The majority of manufacturers therefore offer a basic guarantee which can be extended up to 25 years through the payment of an annual fee. - Almost 70% of the inverters with a capacity of >= 500kW offer a warranty extension of more than 20 years.

Source: CREARA interviews; CREARA research; CREARA analysis

Figure 14—Main characteristics of Warranties and Guarantees for PV Inverters.

The most common problems with PV inverters come from their dimensioning: a PV system with an undersized or oversized inverter will not be as efficient as one operating closer to its peak capacity.

Other problems including the following can arise:

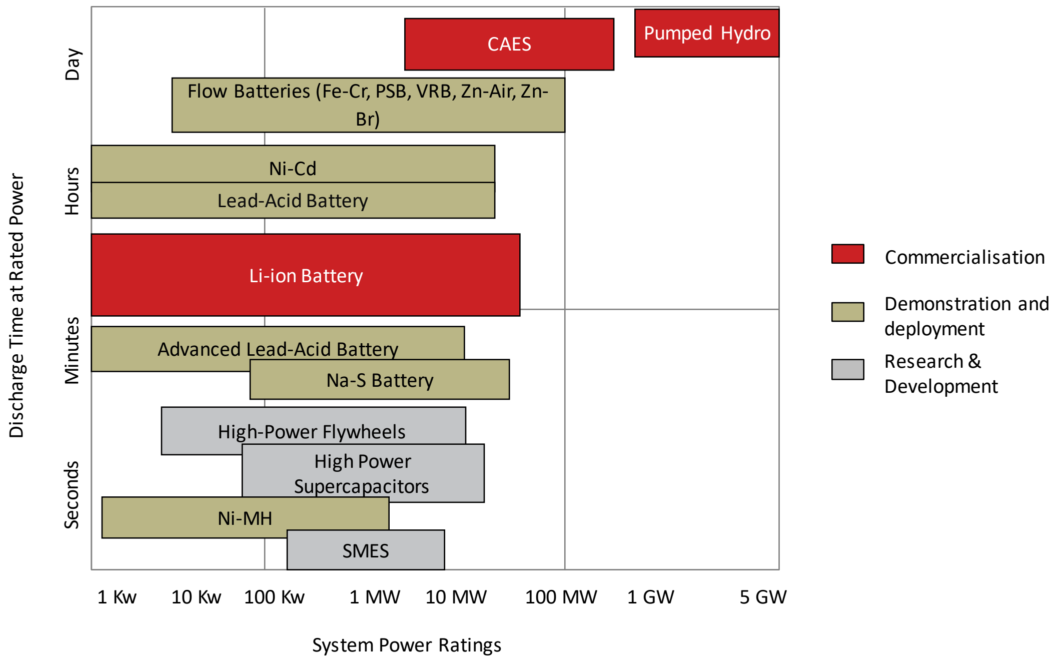
- Lack of ventilation (the inverter can de-rate when reaching maximum temperature).
- Electrical problems, that provoke automatic shutdown of the system.
- Overvoltage, since inverters can sustain excess loads only briefly.
- More stringent grid codes can require that the inverter be updated.

STORAGE

There are several alternative technologies for storing generated electricity. However, each storage system has its own requirements regarding power rating, total energy and speed of power variations, and therefore not all technologies are suitable for all applications.

The current worldwide installed power of grid-connected energy storage systems is approximately 143 GW. Of this capacity, 99% is Pumped Hydroelectric, since it is currently the only technology together with CAES that has been able to offer a cost-effective solution for bulk storage.

Nonetheless, the growth of renewable energy and the introduction of new policies that upgrade the production of electricity are driving the implementation of storage technologies. Battery storage is evolving into a standard product that is offered in combination with solar systems. However, the market is still under development and needs to overcome different barriers such as cost-competitiveness, validated performance and safety measures.



Note: CAES: Compressed Air Energy Storage; SMES: Superconducting Magnetic Energy Storage; Na-S:sodium–sulfur; Ni-Cd: nickel-cadmium; Ni-MH: nickel metal hydride
Source: KEMA; Sandia; EPRI; Fraunhofer Institute; CIGRÉ; ESA; IEA; CREARA Analysis

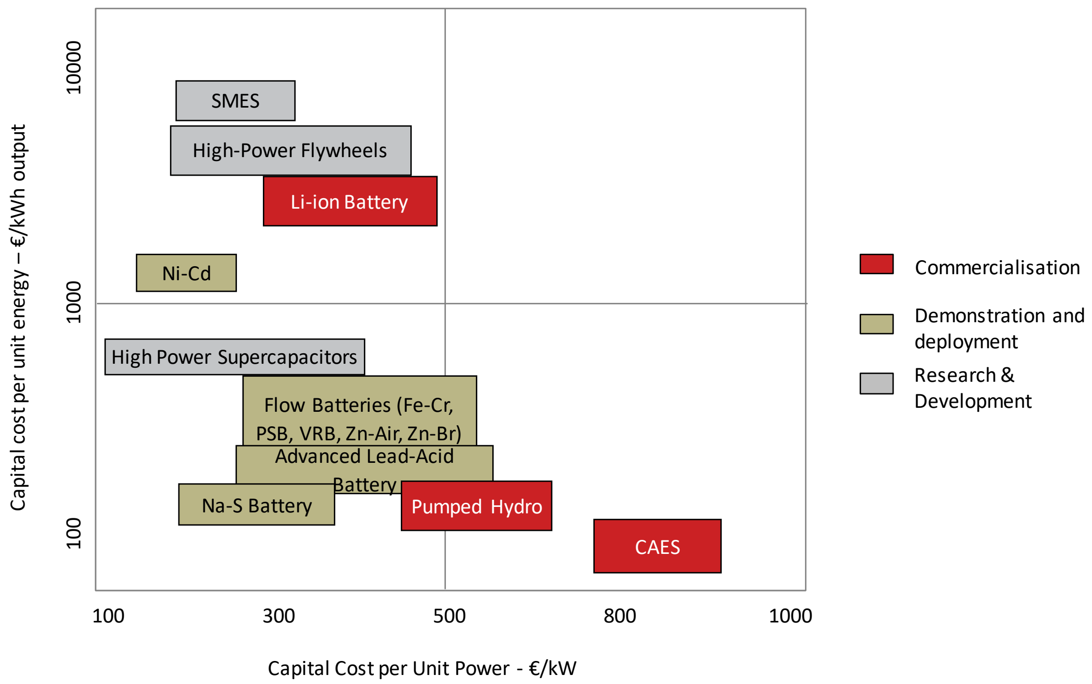
Figure 15—Energy Storage Technologies.

Some battery manufacturers design specific systems for Renewable Energy Sources (RES), in particular those employing Lithium-ion technology. However flow and lead-acid based technologies are becoming more competitive for certain PV applications.

- Investments in the development of lithium-ion technology have increased, reducing their costs and improving their deployment. This process has been driven mainly by its use in electric vehicles (EV) and in the consumer sector. Companies have been able to reduce margins and consequently prices mainly due to an increase in demand for this type of battery. These batteries are currently dominating the utility-scale market, although it is expected to become the industry standard storage technology for households on the long-term.
- Investments in the development of flow batteries have also increased, although to a lesser extent than for Lithium-ion technologies. This type of battery still has to cope with barriers such as premature degradation and high cost.

- Lead-acid storage systems have experienced a clear drop in price in recent years. This decrease is expected to continue in the near future, since they present a clear advantage with regard to the other batteries, namely their strong power performance.

Among the alternative solutions, Lithium-ion technology remains one of the most expensive in terms of the capital investment required, as illustrated in Figure 16.



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Source: KEMA; Sandia; EPRI; Fraunhofer Institute; CIGRÉ; ESA; IEA; CREARA Analysis

Figure 16—Storage Capital Costs per Technology Type.

Some countries, such as Germany, Japan and Australia, have introduced an incentive for residential and small business to install a storage system for PV energy.

- Germany launched an energy storage program in 2013 where up to 100% of the net investment value is eligible for financing. Approximately 27,000 batteries (136 MWh) had been sold as of 30 September 2015.
- Japan introduced a subsidy program in 2012 to encourage the installation of batteries. By the end of 2016, 50,000 storage systems (277 MWh) had been installed.
- Australia signed a battery storage incentive program in South Australia, offering direct subsidies to install batteries for households, businesses, schools and community groups. In Australia, at least 1.5 million households have solar PV systems.

INSTALLATION

The duration of the development process of a PV system ranges from less than a year to 3 years, depending on the size of the installation, and is often composed of the following phases:

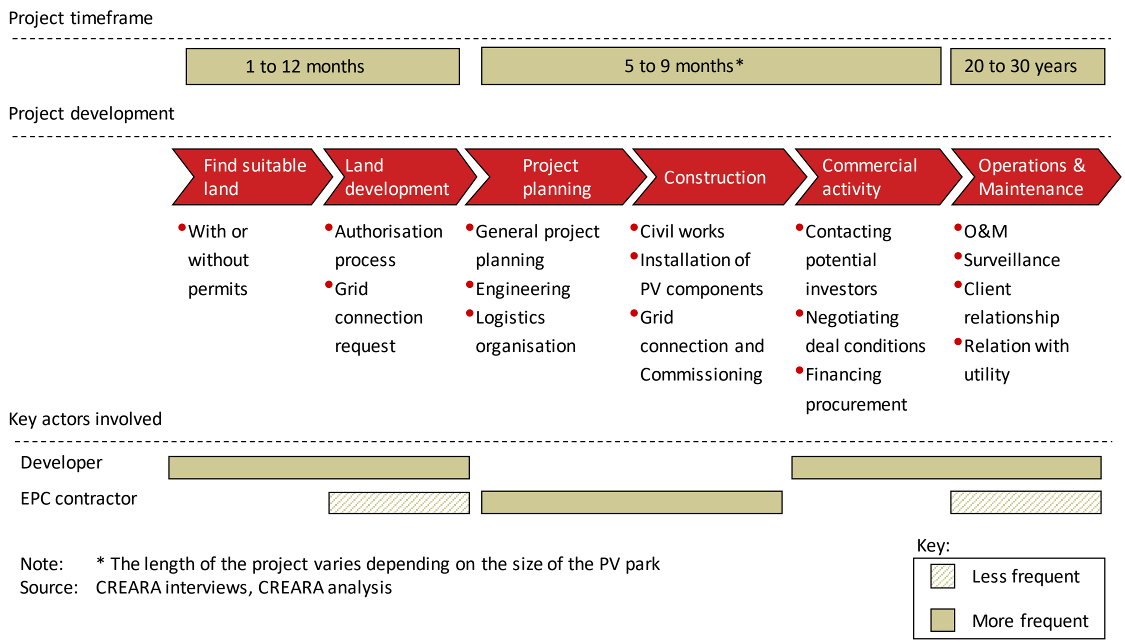


Figure 17—Indicative illustration of the development process of a PV system.

The Engineering, Procurement, and Construction company (EPC) in large systems, or the installer[6] in smaller systems, defines the optimal system design, and coordinates construction. The EPC provides a 2-5 year guarantee for the whole system although the installation of the PV equipment and other activities subcontracted may be outsourced.

The developer of the PV system is in charge of identifying investors, looking for sites, handling administrative procedures and permitting, as well as organizing financing. EPCs increasingly have development capabilities.

EPC AND EPCM

A turnkey (EPC) contract regulates the construction, installation, and commissioning of the PV plant.

- The EPC contractor is responsible for the obligations of its subcontractors and for the performance of the system over a period of 2-5 years.
- The EPC bears the risks of the construction of the PV system, which increases the cost of the contract.

An alternative to the EPC contract is an EPC Management (EPCM) contract, where the risks borne by the EPCM contractor are lower than those under a turnkey contract. The costs of this option are generally reduced.

[6] For small systems, local installers (or electricians) are the rule. For larger systems, local or international EPCs are the classic PV players

- The EPCM contractor is responsible for managing the project: construction, installation, testing and commissioning of the PV system.
- The EPCM selects the EPC contractors and enters into several individual agreements with them (civil works, supply of equipment, installation, other services, et cetera), and does not respond for the obligations of each individual EPC contractor.

PERMIT PROCESS

Depending on the characteristics of PV system (roof/ground, size and location), the permit process for the construction and operation of a PV plant can take between 1 and 3,5 years. The most important administrative procedure is the grid connection application, which can take from 1 to 6 months.

	Details
Grid connection Application	• Information on the characteristics of the PV system should be included (location plan, technical data of the system, inverter information, among others). • After the application, grid verification is performed.
Environmental Impact Assessment	• An environmental impact assessment of the project on the area should be submitted, when applicable.
Construction and building permit	• This permit should be issued prior to construction.
Operating license	• Final registration of the PV installation prior to operation.

Source: CREARA research

Figure 18—Indicative Illustration of the administrative procedures for PV systems.

DIMENSIONING

The developer of the PV system performs the preliminary stages of the dimensioning of the project. The subsequent activities are generally executed by the EPC contractor or the installer.

The dimensioning of a PV system entails various tasks, including but not limited to:

- The energy need that will be addressed by the PV system should be defined: will the PV-generated electricity be sold or will it be self-consumed?
    - If the PV electricity is used for 100% self-consumption, then the power of the system should be set such that it does not exceed electricity consumption, thereby avoiding any excess generation.
- In addition to the nature of the investment, there are other variables that should be considered when estimating the ideal PV system size. These include such things as the particular location (latitude), other local characteristics such as average cloud cover as well as the Performance Ratio (PR).
    - The PR intends to capture losses caused on a PV system's performance by temperature, shade, inefficiencies or failures of components such as the inverter, among others.
- Moreover, the PV system should be dimensioned according to the type of installation (rooftop or ground) and the mounting structure (fixed, single-axis, double-axis).
    - An analysis will be performed to calculate the optimal module tilt angle (this angle is generally lower for roof-mounted systems to mitigate wind resistance).

- Calculating distances between modules and with respect to the ground is important in order to minimize shading and optimize production. The required average space is estimated at 2-2.5 hectares for 1MW of fixed mounted systems, while for trackers it is 4-5 hectares.
- These characteristics determine the suitability and profitability of each alternative. For instance, if the system is a rooftop installation, then the most common alternative is installing fixed mounted structures instead of trackers, which are too bulky and often not optimal from an economic point of view.

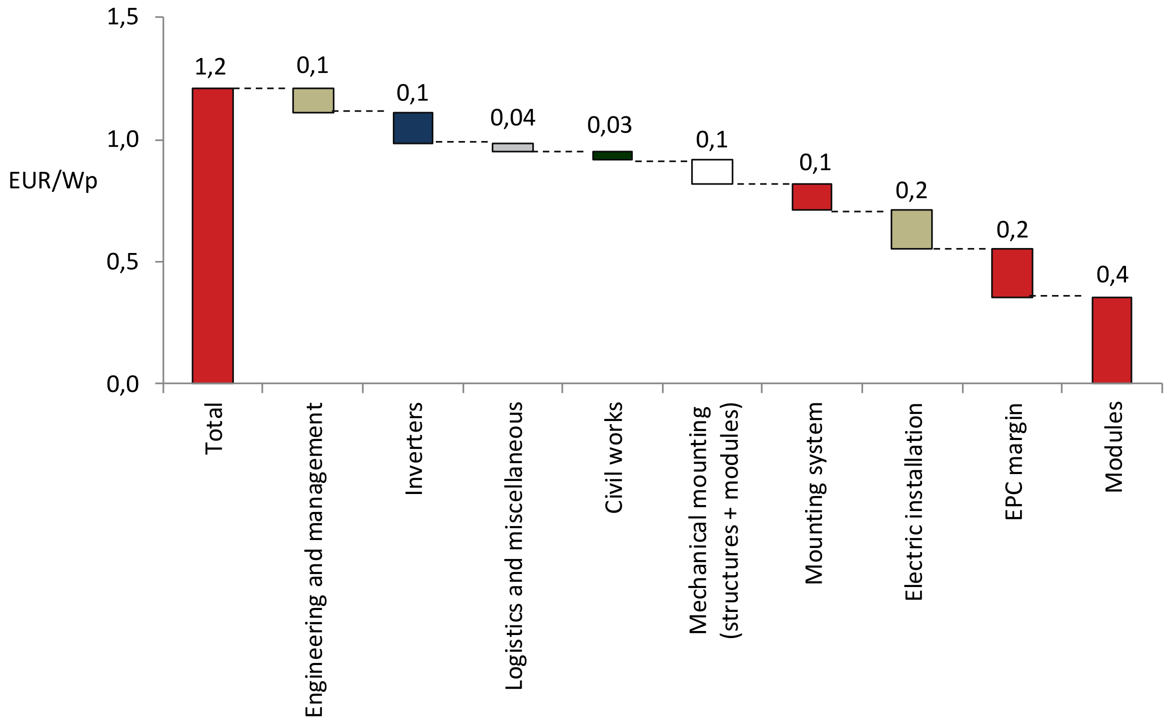
- PV modules arrays are generally placed according to their power and voltage.

A single inverter can be installed for each array of panels or several inverters with greater capacity for the entire system. The latter reduces power losses but increases the risk of greater down time in the event of damage to the inverters.

- In addition, utility connection requirements should be considered. A permit to obtain a grid access point is needed.
  - Once assigned, the line has to be properly designed according to the location of the connection point and the site. Sometimes an underground line is mandatory.
- It may also be necessary to install security equipment such as fences, cameras as well as a communication system to transmit the performance information of the system.

TOTAL INSTALLATION COSTS

Total installation costs for commercial and tertiary sector PV systems can reach up to 1,2 Eu/Wp, where the highest cost component is PV modules, as shown in the Figure 19.



Source: CREARA interviews; CREARA research; CREARA analysis

Figure 19—Segmentation of turnkey cost (Eu/Wp).

Common problems

Potential difficulties may arise in every phase of the development process of a PV system. These should be taken into consideration in order to mitigate risk. They include:

- Identification of risks
- Assessment and quantification of risks
- Risks should be distributed among the different parties though contractual arrangements

Within the land related activities, a number of risks are borne by the investor and the EPC contractor/developer[7], as described below:

	Description	Difficulties	Risks
Find suitable land	• Finding levelled areas in sunny regions close to the grid • Check administrative availability • Negotiating purchase or lease conditions	• Absence of evident sources • Dealing with non-professional actors • Low hit rate	• Uncertainty • Low number of projects • Delays
Land development	• Pursuing the several administrative process • Negotiating with local and regional authorities and utilities	• Securing the support of all stakeholders • Avoiding bureaucratic cul-de-sacs	• Delays • Extra unaccountable costs • Project cancellation
Find developed land	• Finding appropriate developed areas in sunny regions close to the grid • Check that all requirements are met	• Absence of evident sources • Competition from promoters • Closing legal agreements without mistakes	• Extra cost resulting in overall decreased project profitability • Delays • Project cancellation

Source: CREARA research, CREARA analysis

For EPC | For both | For investor

Figure 20—Difficulties and risks in land related activities.

Project planning is complex and requires coordination in order to avoid costly mistakes that can also lead to penalties:

[7] Throughout this Section, EPC will refer to an EPC company with developer capabilities.

	Description	Difficulties	Risks
General project planning	• Coordination of several actors (e.g. installers), equipment (e.g. transformers, modules, structures) deliveries and resources (e.g. money)	• Dealing with a considerable number of variables • Create solid contracts • Acquiring know-how with the minimum number of projects	• Delays in project delivery that lead to penalties • Liquidity issues
Engineering	• Defining an optimal system design combining several elements • Output estimation	• Environmental conditions may introduce unforeseen issues • Incompatibility of components	• Underperformance of the system resulting in penalties (e.g. low productivity, explosions, fire) • Delays
Logistics organisation	• Making sure all components and phases are delivered in time	• Dealing with several providers and vendors with safety margins without long lead times	• Delays in project delivery that lead to penalties

Source: CREARA research, CREARA analysis

For EPC For both For investor

Figure 21—Difficulties and risks in project planning.

The construction of the PV system requires the EPC to allocate a significant number of resources (workforce and machinery) for a short period, and can face the following risks:

	Description	Difficulties	Risks
Civil works	• Accommodate the land for a flawless PV system • Create foundations and wire conducts • Providing security for the construction site	• Requires light and heavy machinery in remote and changing areas	• Faulty civil works lead to unforeseen maintenance issues during construction and/or operation • Delivery delays
PV installation	• Fixing PV mounting structure • Performing state-of-the-art installation of all PV components and transformation units	• Large number of workers for a short period of time • Minimising system losses, faults • Avoiding PV equipment damage	• Long lead times • Poor system performance resulting in delays and penalties • Equipment theft
Grid connection & commissioning	• Verifying that overall system performance is as expected • Reception and acceptance by utility	• Dealing with reluctant and slow utilities	• Incurring in delays and penalties

Source: CREARA research, CREARA analysis

For EPC For both For investor

Figure 22—Difficulties and risks in construction.

As the graphs above show, the EPC/developer bears a higher number of risks than the investor in the installation phase of the project. Each actor will try to mitigate its risks through contracts (such as turnkey contract and insurance) and the terms set in each contract (for instance, the penalties to apply in particular cases such as delays).

FINANCING

This Section provides an overview of the long-term financing alternatives for commercial and tertiary sector PV systems.

There are presently four main alternatives for financing PV systems ranging from 100 kW to 2 MW: Personal/Business Loans, Leasing, Crowdfunding and PV bonds. Project Finance and energy cooperatives are not convenient for these system sizes, given their high fixed costs.

Personal/Corporate Loan

- Banks lend money based on the creditworthiness of the company or the investor. As such, the bank would not be affected by a hypothetical insolvency of the project, as it is the company or the investor who backs the loan.
- In contrast to project finance, it is not necessary for the financial institution to perform a Project Due-Diligence; it is only required that the consolidated financial statements of the parent company (or the income of the investor) be analyzed.
- The cost of financing varies depending on the tenor, the characteristics of the borrower, etc.

Leasing

- A long-term contract is signed between the investor and the financier, where the financier pays the upfront costs of the project and the user pays back the financing through a series of payments via a lease.
- The financier is the owner and operator of the PV system throughout the duration of the contract, while the user benefits from the generated electricity for self-consumption.

Crowdfunding

- The individuals or companies who need financing post their project details on crowdfunding platforms or through banks, with investors providing funding for the development of the project.
- It should be mentioned that crowdfunding has some associated risks:
    - For the project developer, the main risk is not obtaining the needed money in the period set on the platform or by the bank.
    - For investors, the main risk is the loss/reduction of the provided funds in the event that the profitability of the project is lower than expected.
    - There are no standard obligations, although, some users of crowdfunding self-impose obligations, e.g. they choose to keep the investors up to date regularly with the project development in order to increase transparency and credibility

PV Bonds

- In general, a company issues Green Bonds in order to receive financing, mainly from banks or financial institutions, to conduct green projects.
- The funding is returned with the profits generated by the projects once implemented and operational.
- The bonds are usually used for a portfolio of projects which might include other renewable installations.

Investors can face potential difficulties when dealing with financial institutions. These are summarized as follows:

	Difficulties	Risks
Investor	• Convincing the financial institutions of the solidity of the PV investment returns • High fees for lawyers and technical advisors	• High consumption of time with poor results • Being unable to close a financing agreement • Getting a relatively short tenor and high prices • Poor risk coverage • Liquidity issues

Source: CREARA research, CREARA analysis

Figure 23—Difficulties and risks in financing.

Operation and Maintenance

The Operations and Maintenance (O&M) phase of a PV system is of paramount importance as each missed operational day comes at a cost. This Section covers the main tasks of the O&M phase as well as overall costs and possible problems.

O&M tasks

PV systems can be relatively maintenance free. O&M includes corrective and preventive maintenance, including the following tasks:

- Inverter maintenance; this is the most important part of the maintenance process since inverters have one of the highest failure rates of all PV system components
- Module cleaning as needed; usually twice a year
- Maintenance of ground conditions, such as cutting grass and vegetation
- Upkeep of monitoring and power generation systems
- Maintenance of spare parts and warehouses
- On-site constant data monitoring and remote surveillance
- Verification of equipment conditions and replacement of damaged equipment

O&M costs

O&M costs are recurrent outflows of cash that have to be considered when evaluating any PV project. As Figure 24 shows, O&M costs can reach up to 23.3 Eu/kWp a year. Typically, the highest maintenance cost is for spare parts and warehouses[8].

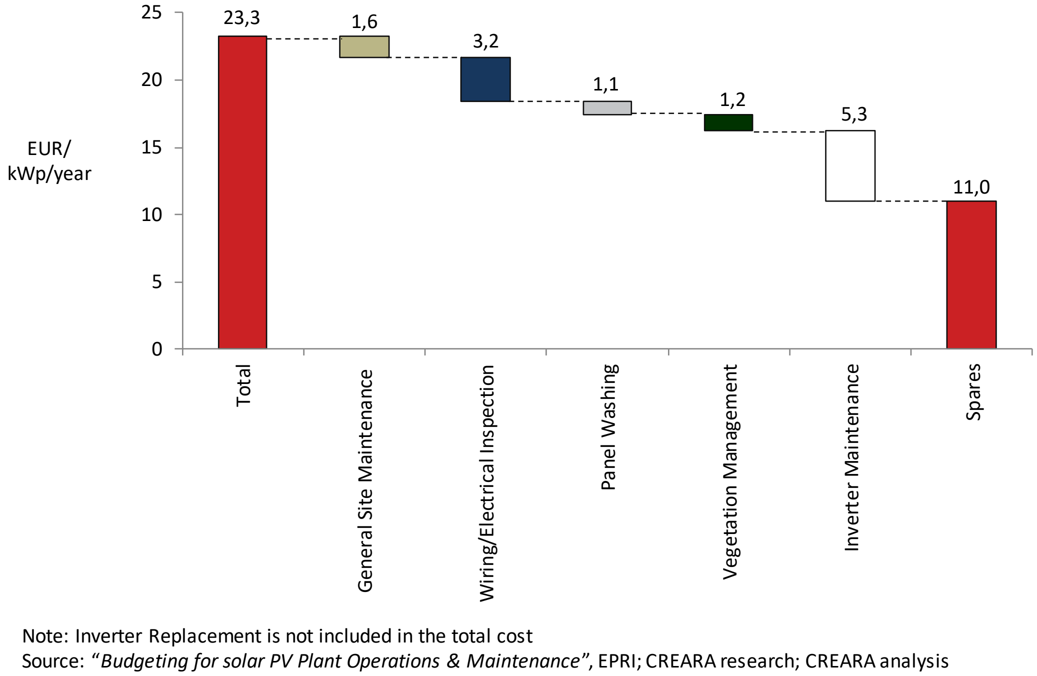


Figure 24—Segmentation of O&M costs (Eu/kWp per year).

[8] It should be noted that the cost for inverter replacement has not been taken into account.

COMMON PROBLEMS

O&M of a PV system entails a set of on-going tasks for a long period. These can involve several difficulties and risks that can affect project cash flows. The investor mitigates the potential cost overruns that can affect the project cash flows through the O&M contract. Therefore, from the standpoint of the actor who performs the O&M service (generally the developer or EPC) the main risks are as follows:

	Description	Difficulties	Risks
System operation and surveillance	• Ensuring stability of system performance • Preventing equipment theft and damage	• Recognising issues soon • Fast response • Minimising surveillance costs	• Decreased productivity resulting in penalties
Client relationship	• Accounting and tax work • Maintaining client satisfaction for some 30 years of system operation	• Ensuring questions are sorted out responsively • Ongoing staff required for a long time	• Unsatisfied client
Relations with Utility	• Ensuring consistency of cash flows with electrical production	• Lack of transparency with utilities	• Decreased cash flows resulting in penalties

Source: CREARA research, CREARA analysis

Figure 25—Difficulties and risks in O&M.

CONCLUSION: ECONOMIC ANALYSIS

This section performs an analysis of the current economic value (expressed as project IRR[9]) of a 2 MWp ground-mounted PV project in terms of different scenarios. The different cases are based on some of the variables that are the main driving forces of the project IRR: EPC costs, irradiation, selling Tariff, and the discount rate.

However, the results presented herein are indicative figures, intended to give an overall perspective of the impact of different inputs in the profitability of a project. Every PV project requires a thorough examination on a case-by-case basis.

The following inputs have been used for the calculations of the financial model:

Concept	Unit	Value
Location	-	Madrid
Installation size	kWp	2.000
System lifetime	Years	25
Turnkey price	Eu/Wp	0,91
Selling price	cEu/kWh	5,03
Annual tariff increase	%	3
O&M costs (% of income)	%	1,0
Insurance Cost	%	2,0
Performance Ratio	%	80
Loss of annual performance	%	0,5
CPI	%	3,0
Corporate Tax	%	25,0
Discount rate	%	6,9

Figure 26—Main inputs of the financial model (base scenario).

IRR

On the basis of an average EPC cost of 0,91 EUR/Wp (base case), other two scenarios were set according to the following assumptions:

- High range EPC cost: 130% of base case
- Low range EPC cost: 70% of base case

As expected, the lower the EPC cost, the higher the profitability of the project. The inverse relationship of these variables is illustrated in Figure 27:

[9] IRR stands for Internal Rate of Return, and is a measure of the profitability of a project.

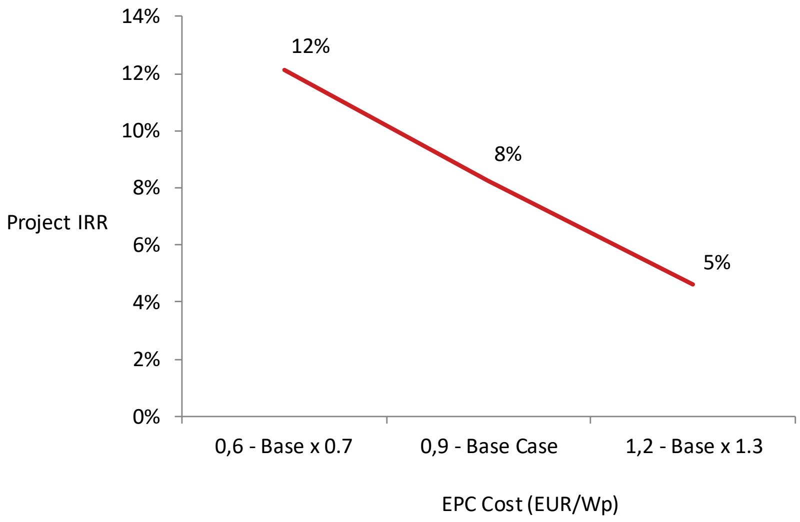


Figure 27—One-way sensitivity analysis of EPC cost on project IRR.

The above Figure shows that a 30% increase in EPC cost causes a 3% fall on project IRR, while a 30% decrease of EPC costs results in a 4% increase in profitability.

Additionally, the effect of different selling tariff levels on project IRR was addressed, and the following scenarios were set:

- Low case: 3.5 cEu/kWh
- Base case: 5 cEu/kWh
- High case: 6.5 cEu/kWh

The impact of this parameter on project profitability is illustrated as follows:

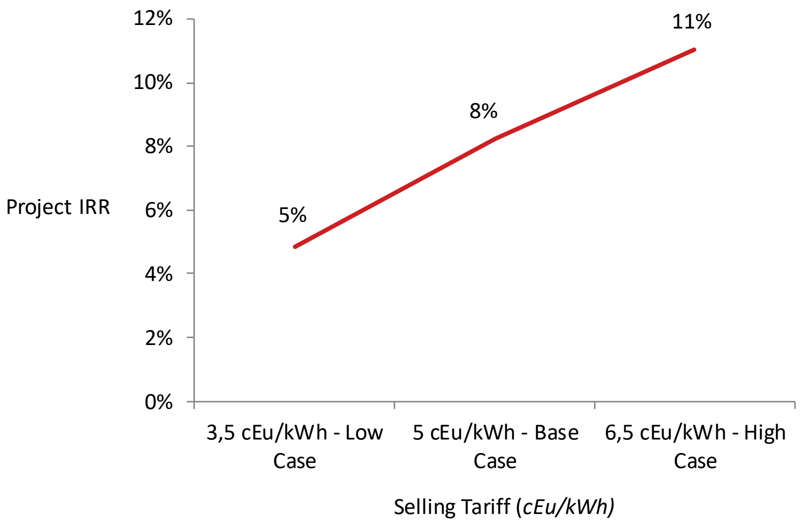


Figure 28—One-way Sensitivity Analysis of selling Tariff on Project IRR.

As the above results show, a 30% increase in the selling price would explain a 3% increase in project IRR, while a 30% decrease in the selling price would cause profitability to fall another 3%.

Moreover, the effect of the irradiation level on the project's IRR was analysed according to the following cases:

- High range irradiation: Copiapó (Chile)

- Mid-range irradiation: Madrid (Spain)
- Low range irradiation: Berlin (Germany)

The average irradiation values at optimal tilt angle for these cities are summarized in the following Table:

Country	City	Irradiation ($Wh/m^2/day$)
Chile	Copiapó	6.870
Spain	Madrid	5.501
Germany	Berlin	2.967

Table 1—Average radiation values at optimal tilt angle[10].

There are significant differences in project profitability according to the location’s irradiation. These are shown in the Figure 29.

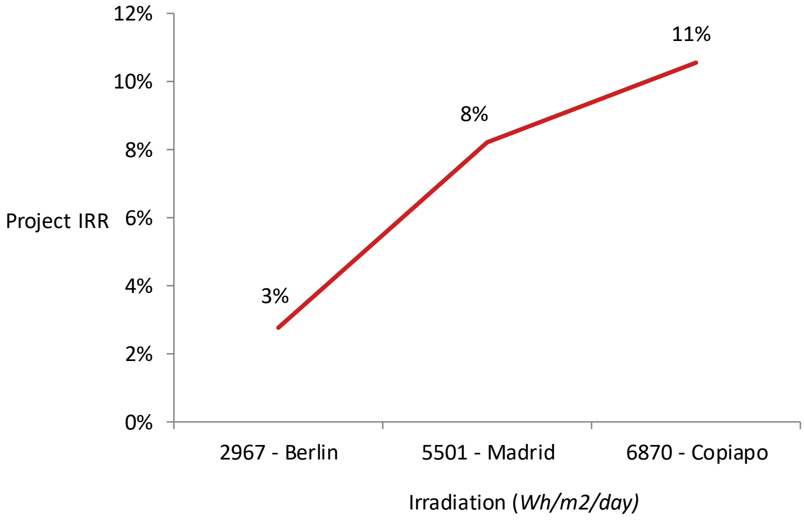


Figure 29—One-way Sensitivity Analysis of Irradiation on Project IRR.

Copiapó has an average irradiation that is 25% higher than that in Madrid, which explains a 3% increase in project IRR. Madrid’s irradiation is 85% higher than that in Berlin, which results in a 5% increase in project IRR.

[10] Source: PV GIS

LCOE

PV Levelized Cost of Energy (LCOE) is defined as the constant and theoretical cost of generating a kWh of PV electricity, whose present value is equal to that of all the total costs associated with the PV system over its lifespan.

PV grid parity is defined as the moment when PV LCOE becomes competitive with grid electricity prices. Once PV grid parity is reached, electricity consumers would be better off by self-consuming PV-generated electricity instead of purchasing electricity from the grid. In this sense, an important distinction should be noted:

- At the residential level, grid parity proximity is assessed by comparing PV LCOE with retail electricity prices (including all relevant taxes such as VAT).
- In contrast, at the commercial level, PV LCOE competes against commercial electricity rates (without VAT, as this cost is borne by the final consumer).
- Finally, from the viewpoint of the power generation player, generation parity refers to the moment when the cost of PV within a given generation portfolio is equal to that of other sources such as a gas fired combined cycle gas turbine.

In the case of some commercial and tertiary sector consumers (e.g. hotels), a good match between PV generation and electricity consumption can be achieved. Although a case-by-case analysis is required to consider each particular demand curve, a commercial consumer such as a hotel could achieve 100% of instant self-consumption by installing a PV system with peak capacity equal to 30% to 40% of its contracted power. Therefore, if a PV system with a higher capacity is installed, additional storage capacity would be required.

A high-level analysis of the PV LCOE of a 2 MWp PV project was performed, on the basis of the following assumptions:

Concept	Unit	Value
Location	-	Madrid
Installation size	kWp	2.000
System lifetime	Years	30
Turnkey price (High LCOE case)	Eu/Wp	1,11
Turnkey price (Low LCOE case)	Eu/Wp	0,7
O&M costs first year	Eu/kWp	60
Performance Ratio	%	80
Loss of annual performance	%	0.5
Leverage	%	70
Debt cost	%	4,7
Debt term	Years	15
Discount rate	%	6,9

Figure 30—Main inputs of the LCOE model.

To evaluate PV grid parity proximity, a commercial and tertiary sector electricity consumer that pays 6.5 cEu/kWh for grid electricity (without VAT, and only considering the variable costs) was considered.

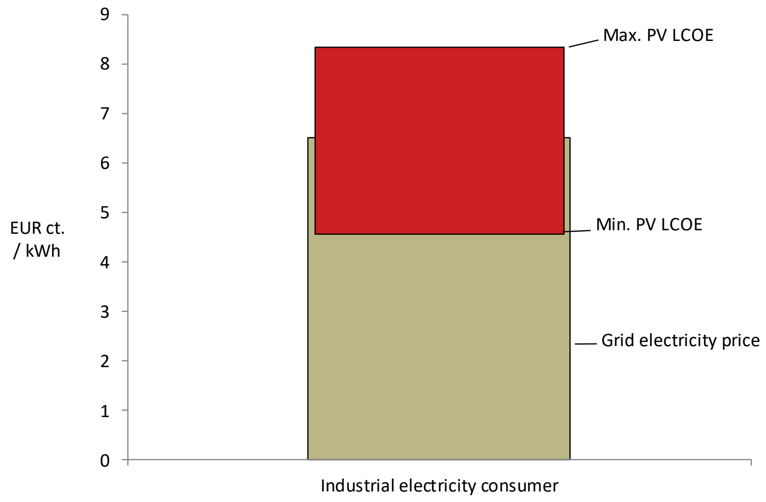


Figure 31—Grid electricity price and PV LCOE for a commercial and tertiary sector consumer.

A sensitivity analysis was also performed to assess the impact of the following variables on LCOE:

Variable	Realistic Minimum	Base Case	Realistic Maximum
Irradiation (Wh/m^2/day)	2.967 (Berlin)	5.501 (Madrid)	6.870 (Copiapó)
Discount Rate	5%	7%	9%
EPC cost (EUR/Wp)	0,8	1,1	1,4
PV system lifetime	20 years	30 years	40 years

Table 2—Summary of data for LCOE calculations.

The above assumptions were included in one-way sensitivity analyses, illustrated in Figure 32.

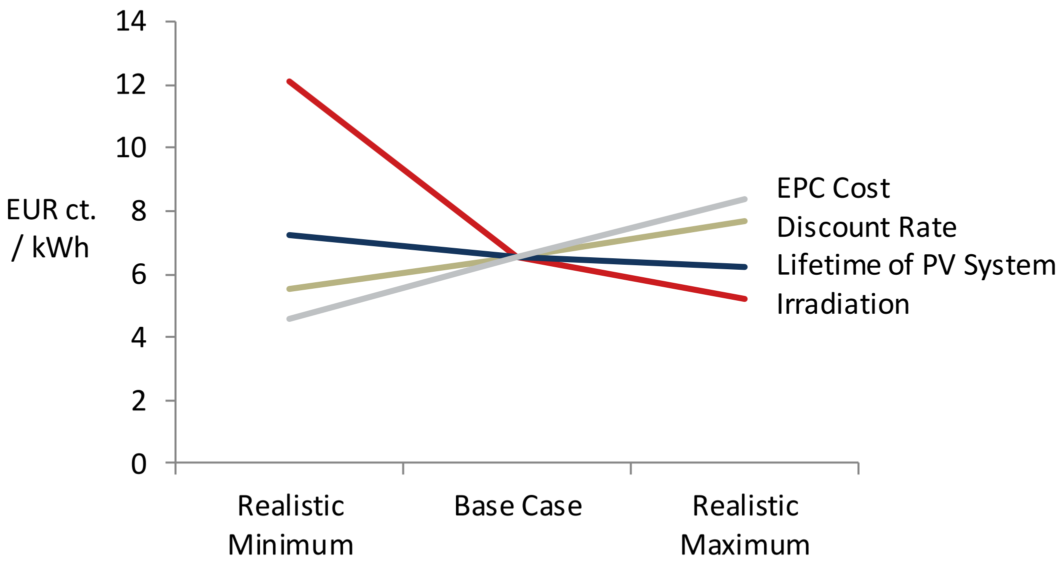


Figure 32—One-way Sensitivity Analysis of Four Parameters on PV LCOE.

The results show that the discount rate and the lifetime of the PV system affect LCOE to a lesser extent than the other parameters analyzed. In contrast, a 30% variation of EPC costs results in approx. 2 Euro cents per kWh change in the same direction. Moreover, if the irradiation of Madrid were replaced for that of Berlin, LCOE would significantly increase (from 7 to 12 Euro cents per kWh), and if replaced for that of Copiapó, LCOE would decrease to 5 Euro cents per kWh.

ANNEX: ACRONYMS

Acronym	Meaning
AC	Alternating current
BAPV	Building-Applied Photovoltaics
BIPV	Building Integrated Photovoltaics
CAES	Compressed Air Energy Storage
CPV	Concentrated Photovoltaic
C-Si	Crystalline Silicon
DC	Direct current
EPC	Engineering, Procurement and Construction
EPCM	Engineering, Procurement and Construction Management
EPIA	European Photovoltaic Industry Association
EU	Euro
EV	Electric Vehicles
FiT	Feed-in Tariff
GW	Gigawatt(s)
ITC	Investment Tax Credits
IRR	Internal Rate of Return
kW	Kilowatt
LCOE	Levelized Cost of Electricity
MW	Megawatt
NM	Net metering
NPV	Net Present Value
O&M	Operation and Maintenance
PPA	Power Purchase Agreement
PR	Performance Ratio
PV	Photovoltaic
REC	Renewable Energy Certificates
RES	Renewable Energy Sources
RPS	Renewable Portfolio Standards
UK	United Kingdom
USD	United States Dollar
VAT	Value Added Tax
W	Watt
Wp	Watt peak

Table 3—Acronym Glossary.