SOLAR PHOTOVOLTAICS

COMPETING IN THE ENERGY SECTOR

ON THE ROAD TO COMPETITIVENESS

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"Solar Photovoltaics Competing in the Energy Sector – On the road to competitiveness" is the first part of a comprehensive study conducted by the European Photovoltaic Industry Association with the support of the strategic consulting firm A.T. Kearney, analysing how Photovoltaics (PV) will become a mainstream player in the energy sector. It will be complemented by a second part focusing on PV grid integration.

Disclaimer: please note that all figures and forecasts provided in this brochure are based on EPIA knowledge at the time of publication.

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EXECUTIVE SUMMARY

Solar photovoltaic technology has proven in recent years that, with the appropriate regulatory framework in place, it can be a major contributor to reaching the EU's target of 20% renewable energy sources (RES) by 2020. Technology improvements and economies of scale have spurred steady cost reduction, which will continue in coming years as the PV industry progresses toward competitiveness with conventional energy sources.

But already today, PV electricity is cheaper than many people think. In the coming years the technology will become even more cost-effective and competitive — and qualify therefore as a vital part of Europe's energy future. **Under the right policy and market conditions, PV competitiveness with grid electricity can be achieved in some markets as early as 2013, and then spread across the continent in the different market segments by 2020.**

To study these trends and consider the conditions under which PV will reach full competitiveness, EPIA has conducted an extensive analysis of 5 markets (France, Germany, Italy, Spain and the United Kingdom). The study, carried out with the support of the strategic consulting firm A.T. Kearney, shines new light on the evolution of Europe's future energy mix and PV's role in it.

Decreasing prices and PV's generation cost

Over the last 20 years, PV has already shown impressive price reductions, with the price of PV modules decreasing by over 20% every time the cumulative sold volume of PV modules has doubled. System prices have declined accordingly; during the last 5 years a price decrease of 50% has been achieved in Europe. **System prices are expected to decrease in the 10 coming years by 36-51% depending on the segment.**

Importantly, there is a **huge potential for further generation cost decline: around 50% until 2020.** The cost of PV electricity generation in Europe could decrease from a range of 0.16-0.35 €/kWh in 2010 to a range of 0.08-0.18 €/kWh in 2020 depending on system size and irradiance level.

This study considers the full cost of photovoltaic electricity generation by using the concept of Levelised Cost of Electricity (LCOE). This concept takes into account all investment and operational costs over the system lifetime, including fuel consumption and equipment replacement. It thus allows a comparison of the cost of producing a kWh of electricity between various generation technologies such as for example PV and a gas-fired power plant – provided all external cost components are also included. To calculate the LCOE, the investment costs, different lifetimes and risk profiles of systems are taken into account, as are the locations of PV systems and their exposure to annual solar irradiance.

To accurately assess the evolution of PV system prices, the study assumes competitive cross-European hardware prices (modules, inverters, structural components) as well as competitive development prices (including the margins for installers). These uniform prices for all countries considered are based on the example of Germany, which has Europe's most mature PV market. This "mature market" assumption intends to reflect the convergence of future prices and margins. But such convergence will be possible only if the right regulatory framework is implemented in a way to encourage more growth of European and international markets. The study does take into account national differences in installed system prices caused by diverse financial climates, VAT and administrative charges/fees, which are not dependent on the level of maturity of a given market.

A competitive solution well before 2020

Competitiveness is analysed by comparing PV's generation cost with the PV revenues (dynamic grid parity) and/or with the generation cost of other electricity sources (generation value competitiveness).

"Dynamic grid parity" is defined as the moment at which, in a particular market segment in a specific country, the present value of the long-term revenues (earnings and savings) of the electricity supply from a PV installation is equal to the long-term cost of receiving traditionally produced and supplied power over the grid.

"Generation value competitiveness" is defined as the moment at which, in a specific country, adding PV to the generation portfolio becomes equally attractive from an investor's point of view to investing in a traditional and normally fossil-fuel based technology.

Before the end of this decade, PV will offer every European citizen the chance to become a "prosumer", producing and consuming his or her own decentralised source of electricity at a competitive price.

Competitiveness of PV electricity for final consumers is defined by this study as "dynamic grid parity". The study demonstrates that with different solar irradiance levels from South to North in the largest European countries, and different market segments, dynamic grid parity will not happen at exactly the same time everywhere in Europe. Given the possible decline in generation cost, **dynamic grid parity could be achieved as early as 2013 in Italy in the commercial segment and then spread all across the continent in the different market segments.**

Generation value competitiveness could be reached as early as 2014 in the ground-mounted segment in Italy and then spread out in Europe to many additional countries by 2020.

While the cost of generating PV electricity will reduce sharply in Europe in the coming decade, the study also shows that any further increase of electricity prices —from 2% to 6.7% yearly on average depending on the respective country considered — will shorten the time needed for PV to become competitive. These rather conservative assumptions are based on historical growth rates.

Sustainable support schemes

Smart deployment of support mechanisms, such as Feed-in Tariffs (FiTs), has helped PV gain a market foothold in many countries of the world, compensating for the difference in cost competitiveness between PV electricity and that of conventional sources.

As that competitiveness gap narrows for the PV sector, due to technology development and parallel decrease of generation cost, PV will be able to rely progressively less on dedicated financial support, leading to the phasing out of such support schemes. This will happen even quicker if internalisation of external effects is implemented for all technologies and subsidies to other energy sources are also phased out, leading to a truly level playing field. Achieving competitiveness should not automatically mean the end of all incentives. Policymakers will need to consider softer sustainable support mechanisms aimed at preserving PV's vital place in the energy mix.

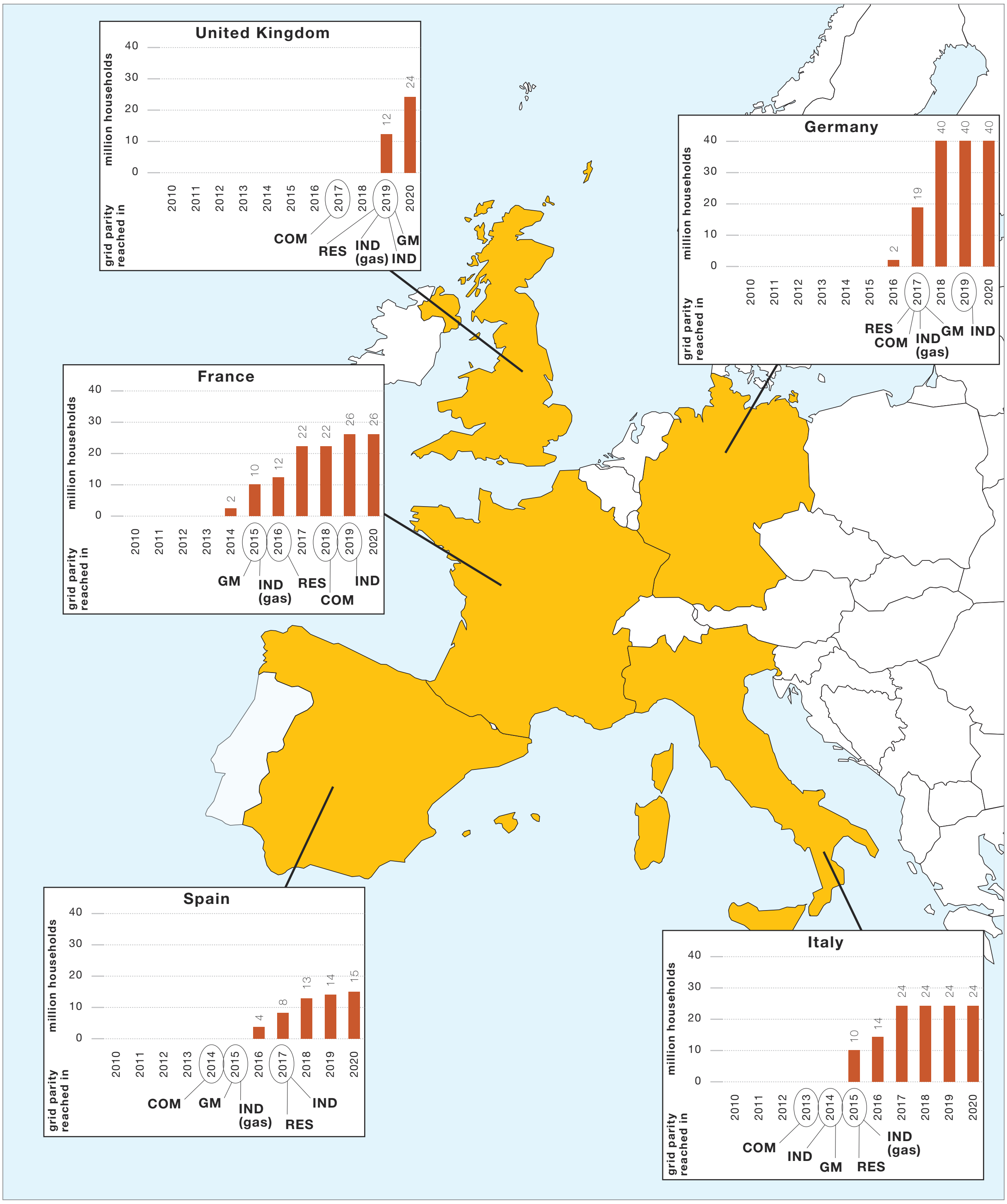
Renewable energy sources, including PV, will be essential to achieving Europe's important goals of reducing greenhouse gases and guaranteeing the security of a safe and local energy supply. Encouraging PV development will also play a major role in the EU effort to create a smart, sustainable economy for the future – one in which high-tech innovation creates jobs and social cohesion. But **an appropriate regulatory framework and favourable market conditions will be needed to ensure that PV can roll-out its full and increasingly promising potential in our future energy mix.**

Switching to solar photovoltaic electricity is not just a desirable option for achieving our energy and environmental goals; it is also a realistic and competitive one.

Main Findings

By determining the full generation cost of PV electricity and comparing it to market trends over the coming decade, this study has reached the following conclusions:

- **Over the next 10 years, PV system prices could decline by 36-51% in all countries and over all segments** (Figure 6, page 16).
- Given increased PV efficiency, economies of scale and the development of mature markets for PV, combined with the growth trend in the generation cost of electricity from all power sources, **PV can be competitive in what are potentially the 5 largest EU electricity markets before 2020.**
- With different levels of solar irradiance from South to North in most of the large EU countries, and different market segments, competitiveness will not happen at the same time everywhere in Europe.
- Figure 1 (page 7) shows the number of households affected by dynamic grid parity every year (for residential systems) as well as the dates when average competitiveness can be reached.
- **Dynamic grid parity could occur as early as 2013 in the commercial segment in Italy and then spread out in Europe to reach all types of installations considered in all the selected countries by 2020.**
- **Generation value competitiveness could be reached as early as 2014 in the ground-mounted segment in Italy and then spread out in Europe to all the selected countries by 2020.** The comparison is done with Combined Cycle Gas Turbine (CCGT) power plants for the reasons outlined on page 25.
- **Achieving PV competitiveness across Europe will, however, require political commitment to regulatory frameworks that support development of the technology and removal of market distortions.**



			France	Germany	Italy	Spain	United Kingdom
Dynamic Grid Parity	Residential (**RES**)	3 kW	2016	2017	2015	2017	2019
Dynamic Grid Parity	Commercial (**COM**)	100 kW	2018	2017	2013	2014	2017
Dynamic Grid Parity	Industrial (**IND**)	500 kW	2019	2019	2014	2017	2019
CCGT generation value competitiveness	Industrial (**IND (gas)**)	500 kW	2015	2017	2015	2015	2019
CCGT generation value competitiveness	Ground Mounted (**GM**)	2.5 MW	2015	2017	2014	2015	2019

Figure 1 - Number of households affected by dynamic grid parity (residential systems) and dates when average competitiveness can be reached

note: households living in the sunniest regions of their country will already be affected by dynamic grid parity before the average dynamic grid parity is reached in the residential segment in their country.

1

PV'S GENERATION COST: UNRAVELLING THE MYTHS

1.1. What is the generation cost?

The **generation cost** refers to the price of a single unit of electricity – normally expressed as one kilowatt hour (kWh). The concept of Levelised Cost of Electricity (LCOE) allows to calculate the real cost of PV electricity and to compare this with the cost of other sources of electricity.

LCOE formula

$$\text{LCOE} = \frac{\text{CAPEX} + \text{NPV of total OPEX}}{\text{NPV of total EP}}$$

CAPEX: Capital Expenditure (investment costs)
OPEX: Operations and Maintenance costs
EP: Electricity Production (in kWh)
NPV: Net Present Value

source: IEA/OECD-NEA.

LCOE represents the cost per kWh and covers all investment and operational costs over the system lifetime, including the fuels consumed and replacement of equipment. **Using LCOE makes it possible to compare a PV installation with any kind of power plant.** For each system the LCOE calculation takes into account:

- The lifetime of the plant
- Investment costs (CAPEX)
- Operational and maintenance costs (OPEX)
- The discount factor (expressed as the Weighted Average Cost of Capital or WACC)
- The location of the plant, which for PV is essential to consider the difference in solar exposure

Technologies, market segments and target countries

Three categories of parameters have been taken into account when calculating PV's generation cost:

Technologies: the two major categories of commercial PV technologies available on the market

- Crystalline Silicon
- Thin Film

Market segments: 4 categories, out of many, cover a large part of the market, from small-scale residential systems to large ground-mounted installations. The typical installed capacity for these segments are the following:

- Residential households: 3 kW
- Commercial buildings: 100 kW
- Industrial plants: 500 kW
- Utility-scale plants (ground-mounted): 2.5 MW

Countries: the countries targeted are the 5 potentially largest electricity markets in Europe, with various combinations of solar irradiance and different country risk and financing conditions. They represent 82% of the European PV market in 2010 ("Global Market Outlook for Photovoltaics until 2015", EPIA, 2011):

- France, Germany, Italy, Spain and the United Kingdom

1.2. Methodology: assessing PV's generation cost in the best way

1.2.a. Components of current and future prices of PV systems

Total installed PV system prices

The starting base for the calculation are the **total installed PV system prices (also referred to as capital expenditure/cost).**

The price of a PV system is split into the following elements (it includes margins taken over the entire value chain):

- **PV modules**
- **Inverter** (enables connection of the system to the electricity grid)
- **Structural components** (for mounting and connecting the modules)
- The cost of **installation** (including the following costs: project development, administrative requirements, grid connection, planning, engineering and project management, construction and margins of the installers)

The **module price** reflected around 45-60% of the total installed system price in 2010, depending on the segment and the technology. Therefore, it is still the most important cost driver.

In order to assess the evolution of PV system prices correctly, a harmonised cross-European hardware cost is assumed (modules, inverters, structural components) as well as standard margins for installers. These are based on the German example and therefore reflect the prices in a mature market. The reasoning behind this "mature market" assumption is that with further growth of other European and international markets, prices and margins will converge globally.

Total system lifecycle cost

When calculating the generation cost, **the total system lifecycle cost** has to be considered, including all costs made over the entire lifecycle of the PV system. Therefore, some additional cost drivers need to be taken into account:

- **Price for operation and maintenance services** (includes margin)
- **Cost of one inverter replacement for each inverter** (because the lifetime of inverters is shorter than that of PV modules)
- **Land cost** (for large-scale ground-mounted systems only)
- **Cost of take-back and recycling** the PV system at the end of the lifetime

Discount factor

The generation cost assessed in the report reflects the technical generation cost, a theoretical value which might differ from the generation cost that can be achieved in the actual market. In practice, the capital cost is usually paid up-front. This represents a significant part of the total investment (around 80-90% depending on the market segment). The remainder of the total cost is paid over the lifetime of the system. On the revenue side, every kWh produced corresponds to a flow of income over the entire lifetime of the system.

As such, all costs and revenues that are not paid up-front have to be discounted in order to come up with a present value. The discount factor used is differentiated across the market segments and the countries. A country-specific risk has been taken into account based on the differences in long-term government bond yields between the five countries assessed. Moreover, a differentiation has been made between private PV owners (residential systems) and business investors (all other market segments).

WACC	Residential	Other segments
France	4.6%	6.8%
Germany	4.4%	6.5%
Italy	5.5%	7.6%
Spain	6.1%	8.2%
United Kingdom	4.6%	6.8%

Table 1 - Assumptions on the Weighted Average Cost of Capital (WACC)

It should be clearly noted that the cost of capital mentioned in Table 1 (page 11) do not reflect the full cost of financing PV systems. While they take into account the stability of the financial climate in the different countries, they do not reflect how financing institutions perceive PV technology today and in the future. As such, the current discount factors used by individual and institutional investors are most likely higher. Given that the awareness of financing institutions is rising and that PV is more and more being perceived as a low-risk investment, the current return asked by investors in PV could start to decline. **From the current levels of 6-8% in the residential segment, the requested return could go down to 4.4-6.1%; in the other segments, a similar decrease from the current 8-12% to 6.5-8.2% could be achieved** in the target countries of this study once awareness of the real risk is widely spread and risks related to the political environment are lifted. Failure to achieve this would result in the LCOE of PV remaining higher than it could be, delaying the competitiveness of PV by an average of one year.

Assumptions on the evolution of future system prices

Determining PV's generation cost in 2, 5 or 10 years requires an assessment of how PV system component prices could go down in the future. Since this depends heavily on market evolution, an intermediate scenario was chosen: from 2010 to 2015, EPIA's Policy-Driven scenario ("Global Market Outlook for Photovoltaics until 2015", EPIA, 2011) is taken into consideration. After 2015, EPIA's Accelerated Growth scenario, based on Greenpeace and EPIA's "Solar Generation VI" PV market development scenarios, is considered. The technology split is based on the "Solar Generation VI" report.

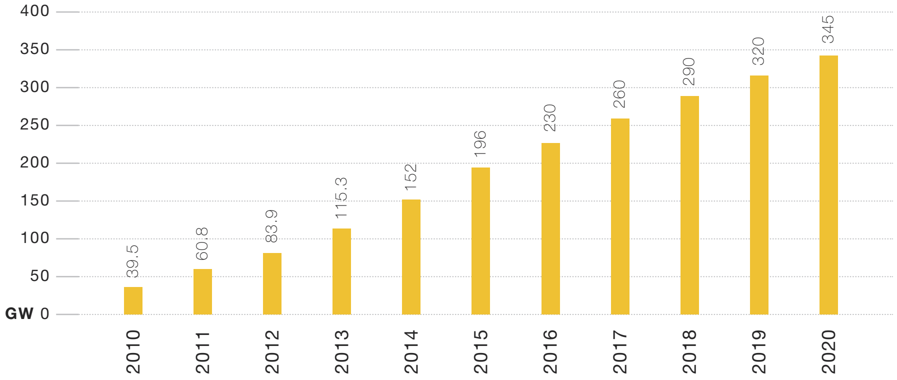


Figure 2 - Market evolution assumption (cumulative installed PV capacity 2010-2020)

- **PV modules: an initial learning factor of 20% has been assumed**. For every doubling of the cumulative volume sold, the price will decrease by 20%. Whereas for Thin Film PV modules the learning rate is assumed to remain 20% until 2020, this rate could decrease towards 15% for Crystalline Silicon modules in 2020.
- **Inverters:** a learning factor of **20% has been assumed for small-scale inverters** (used in residential systems) and of **10% for large centralised inverters** (used in all other market segments). The learning factors are based on the realised price reductions in the PV industry since the 1980s-1990s.
- **Structural components:** the evolution of the cost of some components, such as cables and mounting structures, depends on the evolution of raw material prices, scale and learning effects. However, a significant part of their costs are influenced by PV module efficiency: the higher the efficiency, the fewer structural components are required. Therefore, **the efficiency evolution of the modules has been taken into account**, based on the roadmaps developed by EPIA and the European Photovoltaic Technology Platform (Source: “Strategic Research Agenda” and “Solar Europe Industry Initiative - Key Performance Indicators”, European Photovoltaic Technology Platform, 2011).
- **Installation cost:** the parameters that have been taken into account are similar to the ones that determine the evolution in the price of the structural components. The increase in labour cost is taken into account as well.

1.2.b. Parameters for the calculation of PV electricity production

To calculate the cost per kWh of electricity produced, the total energy output of the PV system has to be determined. This includes several parameters:

- **Solar irradiance**: the data on solar irradiance are based on the PV-GIS database from the Joint Research Centre of the European Commission and the SolarGIS database from Geomodel Solar. Extreme values (5% on each side) for each of the countries have been discarded.
- **Performance ratio**: during the day, a PV system does not produce at 100% of its capacity due to for example shading of the modules. The general standard is to assume about 75% for residential systems and 80% for larger systems.
- **Lifetime**: to calculate generation cost, based on continuous technology developments, a gradual increase of the technical guaranteed lifetime of the PV modules, starting at 25 years and increasing to 35 years in 2020, is assumed. The same has been done for inverters (15 years in 2010 to 25 years in 2020). The technical guaranteed lifetime of the components does not necessarily coincide with the time horizon considered by investors in PV.
- **PV module degradation**: this affects the performance of the PV system over its lifetime. The assumption is based on the generally accepted guaranteed performance of the PV modules – namely 80% of the initial performance after 25 years. For the purposes of this report, the lifetime used in the calculations is called the guaranteed lifetime. The increase in lifetime reflects improvements in degradation ratios over the years with a guaranteed lifetime of 80% of the initial performance after 35 years for modules produced in 2020.

1.3. A huge potential for cost reduction

1.3.a. PV module prices: a 20% learning factor

The cost of PV systems has been going down for decades and is now approaching competitiveness. The figures below illustrate that remarkable price decline: over the last 20 years, PV has already shown impressive price reductions, with **the price of PV modules decreasing by over 20% every time the cumulative sold volume of PV modules has doubled (learning factor).** The average price of a PV module in Europe in July 2011 reached around 1.2 €/W; this is about 70% lower than 10 years ago.

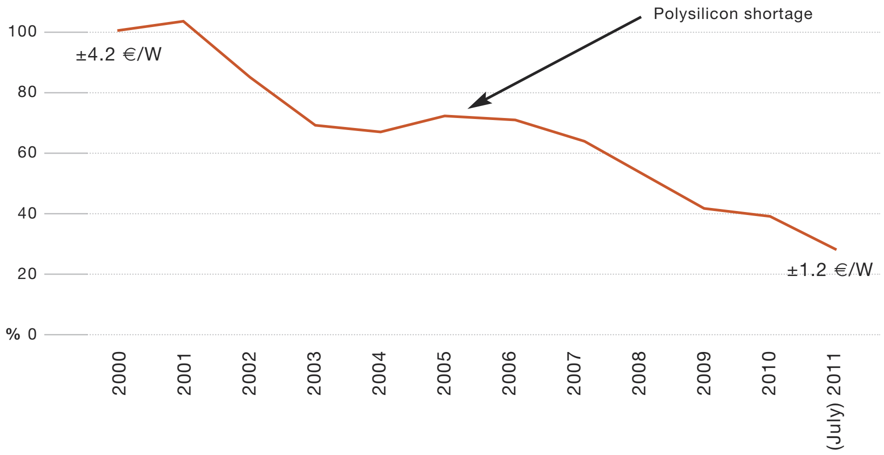


Figure 3 - Evolution of the average PV module price in Europe

source: Price data based on Paula Mints (Navigant Consulting).

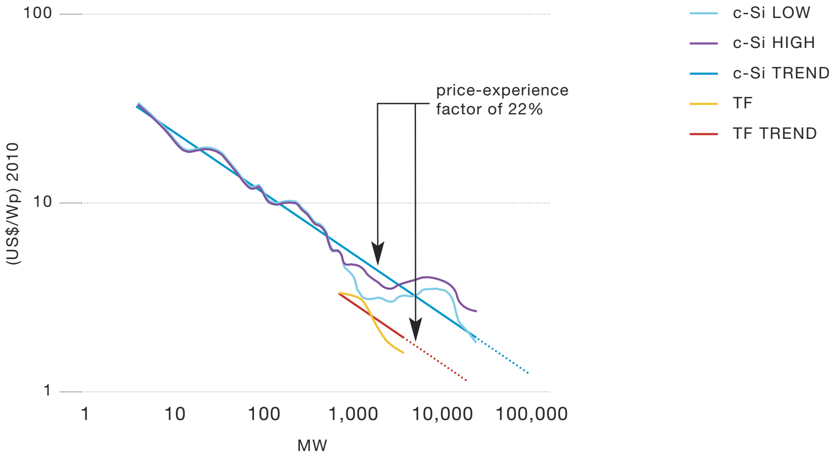


Figure 4 - PV module price experience curve (US$/Wp & MW)

note: Prices in figure 4 are expressed in 2010 US Dollar.
source: Navigant Consulting, EPIA.

1.3.b. System prices could go down by 36-51% by 2020

The cost of an investment in a PV system is driven mostly by the initial up-front investment or capital expenditure. Additional costs encountered during a system's lifetime are comparatively low. Therefore, it is useful to assess the evolution of the capital costs over time.

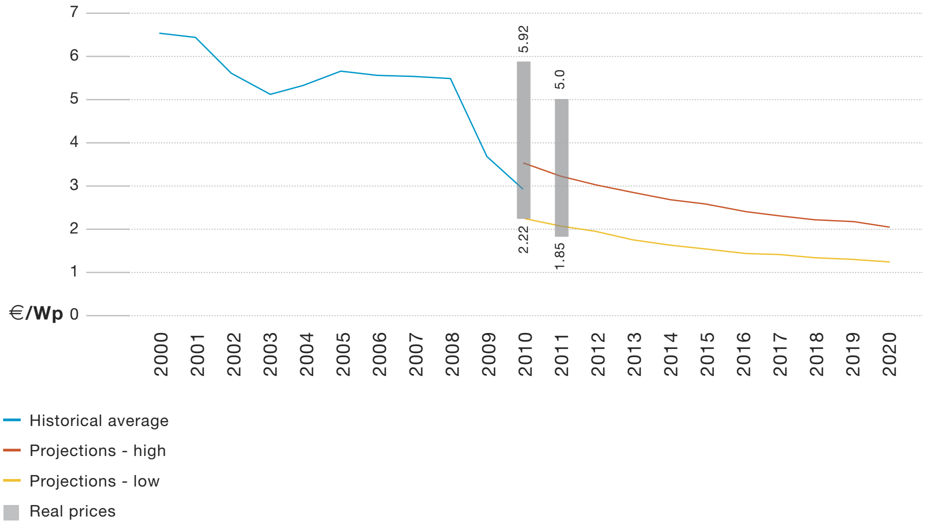


Figure 5 - Evolution of the PV system price in Europe

source: Historical prices based on IEA-PVPS Task 1, EuPD, ASIF and EPIA.

System prices have declined rapidly; during the last 5 years a price decrease of 50% has been realised in Europe. **Over the next 10 years, system prices could decline by about 0.83-1.59 €/Wp** (Figure 6, page 16) – **a price decrease of 36-51%, depending on the segment.** Again, in all countries and over all segments, significant reductions in the total installed system prices are feasible. The observed market prices in several countries contrast with the lowest prices in Germany, where the market is more mature. But that gap is narrowing quickly.

Fast price decline: forecasts confronting reality

While 80% of the global PV market is in Europe ("Global Market Outlook for Photovoltaics until 2015", EPIA, 2011), 80% of modules are assembled elsewhere. That means international trade dynamics will have an important impact on the price of PV systems in the coming years. Fluctuations of the US Dollar and the Chinese Renminbi against the Euro could clearly affect PV system prices in Europe. In addition, the relative dormancy of the PV market in Q1 and Q2 2011 seems to have pushed prices down. While this does not change the long-term prospects for price decrease for the PV market, the continuous decrease as depicted in Figure 5 must be considered as a trend more than a clear roadmap.

The lack of maturity of several PV markets in Europe has kept prices in most EU countries higher than in Germany. There is no single, easily remediable reason why PV system prices are higher in some countries than in others; rather, there are many factors to explain the current price variance. Labour cost is not sufficient to account for any major difference. However, smaller markets with a lack of competition, political choices that only favour the most expensive PV systems, as well as administrative rules and grid connection procedures that increase the time to market could impact the price level significantly. Moreover, unsustainable support schemes could also artificially slow down the price decrease.

The figure below represents the potential for price decrease in 3 market segments – residential, commercial and ground-mounted – starting from the prices seen at the end of 2010. Real prices for 2010 and 2011 are also shown. Prices went down sharply at the beginning of 2011, a consequence of a slow market start and a growing global production capacity.

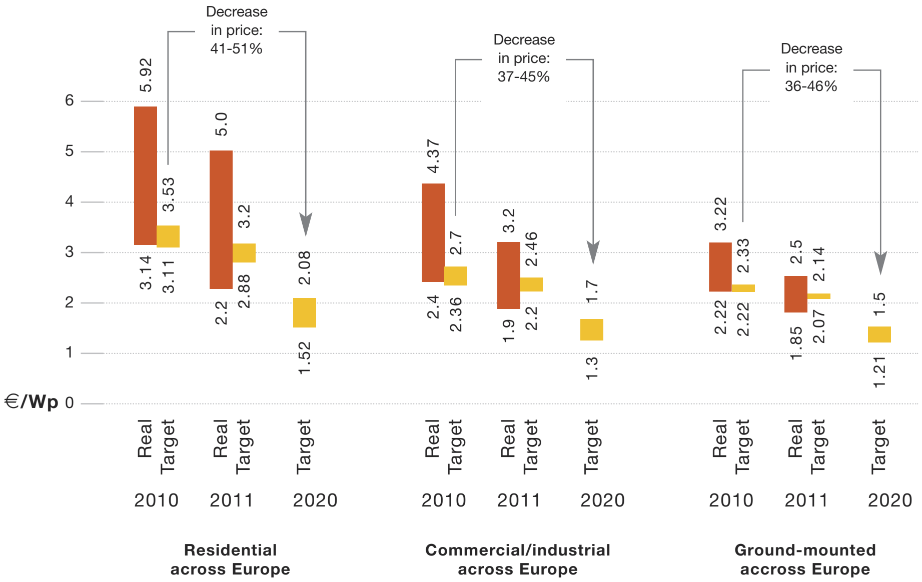


Figure 6 - Potential of PV system price decrease in Europe

1.3.c. Generation cost could decline by 50% until 2020

The results shown in Figure 7 (page 17) indicate a wide range for PV's generation cost in Europe as well as a **huge potential for cost decline: around 50% until 2020.** This wide range is due to the large set of differing parameters taken into account:

- 2 different sets of technologies
- National differences among the 5 countries studied with respect to irradiance levels, financial conditions (including VAT for the residential segment), total installed PV system prices and operation and maintenance costs
- 4 different market segments

The study assumes competitive cross-European hardware prices (modules, inverters, structural components) as well as competitive development prices (including the margins for installers). The range below therefore reflects the generation cost assuming mature market prices. Accordingly, the **average European LCOE for 2010 (0.239 €/kWh) and for the first half of 2011 (0.203 €/kWh)** is shown in the figure below. This calculation considers the real market volumes and market segmentation in Europe.

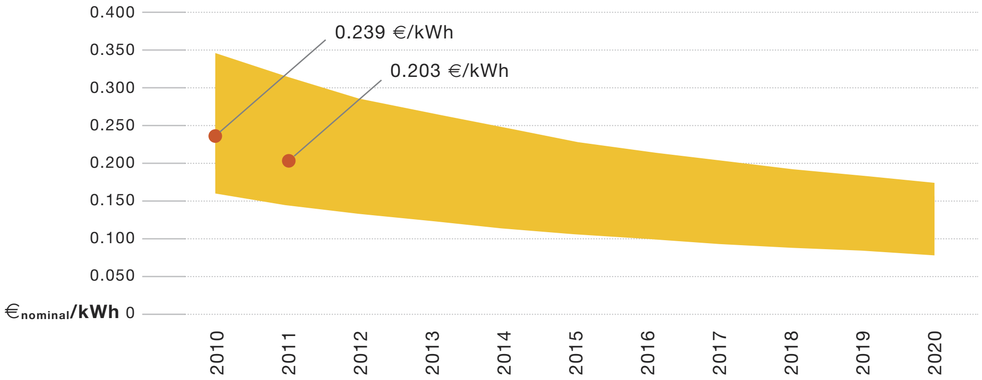


Figure 7 - European PV LCOE range projection 2010-2020

The 2020 range narrows to almost half of the range in 2010. The range reflects the 4 different market segments and the 5 countries covering a large part of Europe.

Reaching market maturity

Figure 7 represents the potential range of PV's generation cost in Europe from 2010 to 2020 if all markets were to behave in the same way as Germany, where the lowest prices are seen at the time of this study. Failure to reach market maturity in some countries would result in non-optimal prices, keeping the generation cost higher.

Maturity refers to specific conditions:

- Reduced margins
- Experienced network of installers, developers and retailers
- Fair competition between players
- Transparent and efficient administrative rules and grid connection processes

Some conclusions

The decline in generation cost is relatively stable across all market segments. Figure 8 shows that, in each of the countries studied, attractive generation costs can be reached within the next 10 years in all market segments considered.

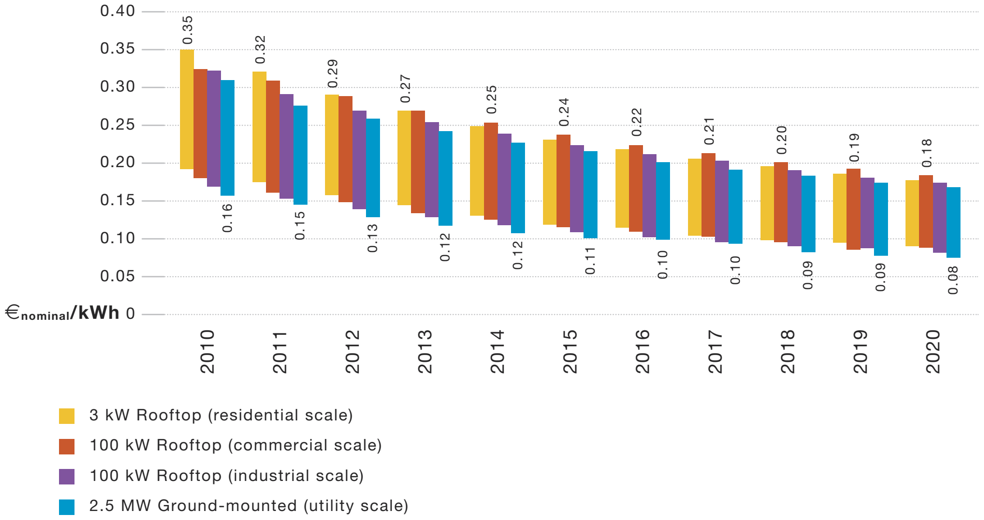


Figure 8 - European PV LCOE range projection 2010-2020 by segment

In Figure 9, the potential range of PV's generation cost in Europe from 2011 until 2020 is shown in relation to the irradiance levels. Higher irradiance levels are of course a driving factor for lower generation costs. The figure however demonstrates that **attractive levels of generation cost could be achieved even in less sunny Northern European regions.** The current real range of PV's generation cost in Europe is also depicted.

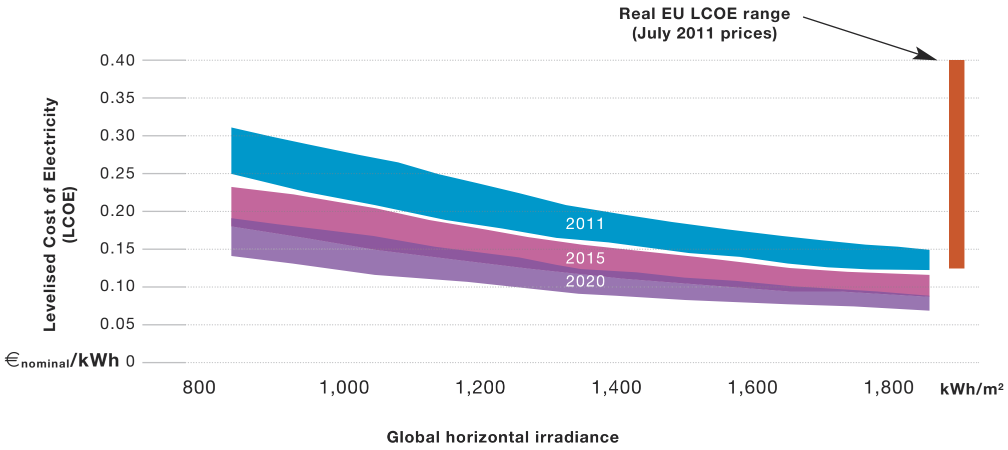


Figure 9 - European PV LCOE range projection

2

PV COMPETITIVENESS: A ROADMAP TO 2020

The competitiveness gap between PV and conventional energy sources is narrowing quickly and a phasing out of the support schemes that have helped compensate for it will be observed. This chapter analyses when PV competitiveness could be reached.

Competitiveness is analysed by comparing PV's generation cost with the PV revenues (dynamic grid parity) and/or directly with the generation cost of other electricity sources (generation value competitiveness).

But electricity price increases and PV's generation cost decreases will not happen at the same time everywhere; rather, they will be affected by many factors. The various factors that will influence the time it takes to reach PV competitiveness are assessed in this chapter. It is important to define what is meant here by competitiveness.

2.1. Competitiveness – Two perspectives: prosumers and utilities

Two specific situations should be considered:

- **Residential, commercial and industrial segments – the local consumption of PV electricity**: when an electricity consumer invests in a PV system that will provide a part of his electricity needs at a competitive price, he goes from being a consumer to a "prosumer". The size of the system does not matter as long as a part of the electricity produced is locally consumed. Hence, residential, commercial and industrial applications are taken into consideration. In this case, competitiveness of PV is defined as **dynamic grid parity.** Assessing dynamic grid parity requires determining the moment at which, in a particular market segment in a specific country, the present value of the long-term revenues (earnings and savings) of the electricity supply from a PV installation is equal to the long-term cost of receiving traditionally produced and supplied power over the grid. In other words: PV will reach dynamic grid parity when the electricity produced by the PV system throughout its lifetime is at least as competitive as the electricity bought from the grid – now and in the future.

- **Industrial and ground-mounted segments – the generation of PV electricity for grid injection**: PV is increasingly being integrated into power generation portfolios of power utilities and independent power producers as a new source of electricity production. Given the current peak-load generation profile of PV (producing mainly during mid-day peak when gas turbines are usually running), its competitiveness will be assessed by comparing it to a standard Combined Cycle Gas Turbine (CCGT) power plant. In other words: PV will reach competitiveness as a power generation source when, from a financial point of view, its generation cost (LCOE) is at or below the level of a new CCGT power plant. This is defined as **generation value competitiveness.**

"Dynamic grid parity" is defined as the moment at which, in a particular market segment in a specific country, the present value of the long-term revenues (earnings and savings) of the electricity supply from a PV installation is equal to the long-term cost of receiving traditionally produced and supplied power over the grid.

"Generation value competitiveness" is defined as the moment at which, in a specific country, adding PV to the generation portfolio becomes equally attractive from an investor's point of view to investing in a traditional and normally fossil-fuel based technology.

2.2. Methodology for dynamic grid parity – Competitiveness for prosumers (residential, commercial and industrial segments)

This part analyses the 3 following market segments, on the ability of PV electricity to compete with the retail price of electricity paid by consumers:

- Residential customers, with systems around 3 kW
- Commercial customers, with systems around 100 kW
- Some industrial customers, with systems around 500 kW

With electricity prices expected to rise in the coming decade in all EU countries, assessing the profitability of any investment based on today's prices and costs has limited value.

The "dynamic grid parity" concept involves comparing the present value of a PV investment (the cost of generation cost or LCOE, as previously explained) and the present value of all revenues from the production of electricity by the PV system.

Those **PV revenues** can be split into 2 parts:

- The **savings on the electricity bill** (when PV electricity is directly consumed on-site, leading to a reduction of total electricity demand)
- The **earnings from the sale of excess PV electricity**

This comparison is done over the **full PV project's lifetime: currently 25 years but increasing to 35 years in 2020**, as technological improvements over the coming decade are expected to extend a typical PV system's lifetime.

Excluding BIPV systems

The specific case of BIPV (Building Integrated Photovoltaics) systems has not been analysed in this study. BIPV is an application that can reach its full potential in 2 separate market segments – new buildings and major renovations.

BIPV aims to replace part of the traditional building materials (tiles, glass) with a PV panel, with a possible price reduction in comparison to a classic rooftop installation. The cost of saved materials and the reduced manpower will drive prices down or compensate for the additional costs of some innovative BIPV equipment. For existing buildings, however, the need to replace materials will result in increased costs compared to standard rooftops, delaying the moment when parity is reached.

2.2.a. Savings on the electricity bill

The current way that FiTs for PV electricity are defined treats consumers and producers of electricity as if they are living in separate worlds. This does not help consumers to see the direct benefit of PV; the reduction in their electricity bill requires being able to consume their PV electricity instead of buying it from the grid. For that reason, some countries have established **compensation schemes that allow the use of PV electricity for local needs**. Two of those schemes are **net-metering and self-consumption.**

In a **net-metering** scheme, **the total production during a predefined period can compensate part or all of the electricity consumption over the same period**. Depending on the regulatory framework, either the price of electricity can be compensated (representing only a part of the electricity bill) or the whole bill. Some intermediary schemes exist today with a partial refund of some grid costs.

Self-consumption implies that **local production from PV compensates in real time** (actually over a 15-minute period) **local consumption**. Excess production is then injected on the electricity network while additional consumption requires buying from the grid.

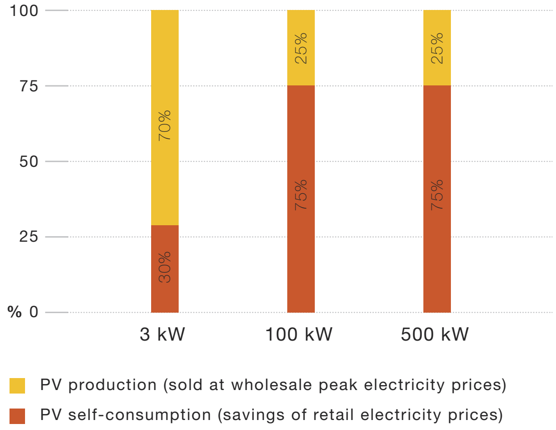


Figure 10 - Assumptions on the share of self-consumption

While net-metering schemes can be adequate to raise awareness among consumers, the study considers the most conservative option in order to estimate when dynamic grid parity could be reached (Figure 10, page 21):

- **A 30% self-consumption rate was chosen for residential applications** (meaning 30% of PV electricity production is immediately consumed locally while the remaining 70% is injected on the network; the additional demand for electricity is of course bought from the grid). Higher shares could be reached with phased consumption for instance by using electric vehicles.
- **For commercial and industrial applications, a higher level of 75% of self-consumption is considered**. Commercial and industrial applications can deliver electricity during weekdays when there is increased consumption, which is less often the case with residential applications as homeowners are usually out of their houses during weekdays.
- Higher levels of self-consumption could be reached (net-metering reaches 100%) using specific methods, such as local storage or demand side management tools. However, those options have not been considered within the scope of this study for the time being since they are not yet commercially available on a large scale and/or would require additional investments.

2.2.b. Earnings from the sale of excess PV electricity

While a part (30-75% as stated above) of the PV electricity will be consumed directly, the rest of the electricity will be injected on the grid, just as any electricity producer would do. This study assumes that this electricity could be sold at a reasonable price. This price is computed using the average price of electricity on the wholesale market during the peak period. Peak period refers to the moment when PV is producing electricity: from 8 A.M. to 8 P.M. during weekdays. Weekends were not taken into consideration, with higher consumption in the residential segment and probably equal or slightly lower consumption in the commercial and industrial segments.

For all 5 countries assessed in the study, the average wholesale peak prices considered in 2010 were the following:

	€/MWh	2007	2008	2009	2010
France	Average	58	92	58	59
	Maximum				252
Germany	Average	56	88	51	57
	Maximum				180
Italy	Average	103	113	82	76
	Maximum				175
Spain	Average	46	71	40	42
	Maximum				91
United Kingdom	Average	44	103	54	57
	Maximum				369

Table 2 - Wholesale peak electricity prices in Europe

2.2.c. Other assumptions

Grid costs

The price of electricity paid by consumers can be split into at least 3 parts: the price of electricity itself (with margins taken by intermediaries), **grid costs** and finally **taxes**. Grid costs are meant to finance the operation, maintenance and development of the grid, at both distribution and transmission levels. A part of grid costs is traditionally fixed (5-10%) and the remaining part is variable (linked to the amount of kWh consumed).

The study assumes that, in the case of self-consumption, the compensation of the electricity bill will not include fixed grid costs.

While the share of fixed grid costs remains quite low with regard to the total grid costs, EPIA estimates this situation will change in the future to compensate for the bi-directional use of the grid (when excess electricity is injected on the network) and the decrease of electricity consumption (due to self-consumption). This has not been considered here, since competitiveness could be reached in most major EU countries before this will have a significant financial impact on grid operators.

Trends in electricity prices

The growth trend in electricity prices is another factor to be taken into account. The assumptions are based on historical growth rates and are therefore rather conservative.

Two separate but interconnected price evolutions are used in this study:

- **The retail electricity prices refer to the prices paid by consumers**. These retail prices can be compensated by the savings generated from the electricity production of PV systems.
- **The wholesale peak electricity prices refer to the prices that utilities pay or receive**. For the purpose of this study, it is assumed that these are also the prices at which excess PV electricity can be sold.

Retail electricity prices for consumers are expected to grow in the coming decade. The assumptions are based on already known price increases or expected growth. In this decade, **electricity prices for final consumers could increase from 2% to 5.4% yearly depending on the country. The prices of electricity in all segments are affected**.

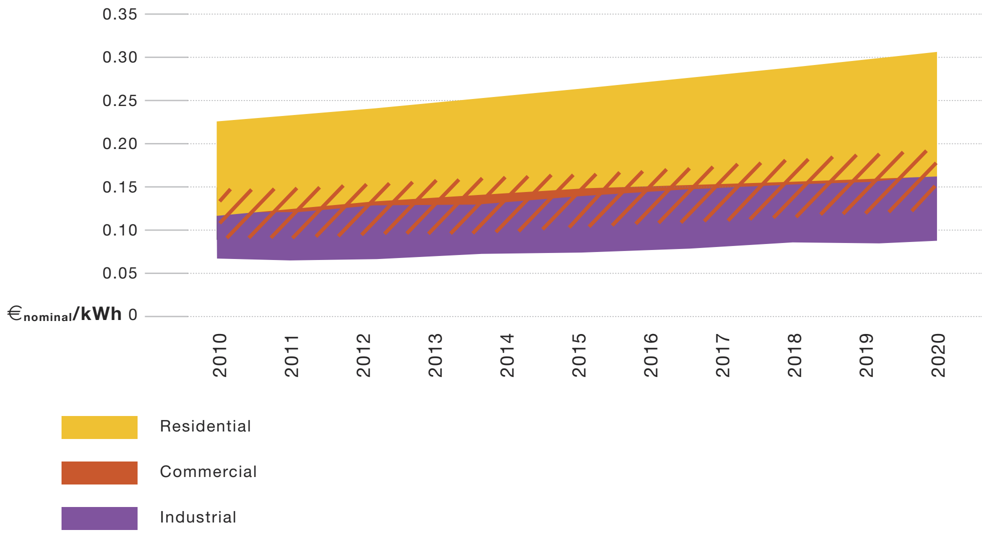


Figure 11 - Assumption on the increase of retail electricity prices for different types of consumers

	Residential			Commercial			Industrial			All
	CAGR 2000-2007	**CAGR 2008-2010**	**Forecast CAGR 2011-2020**	**CAGR 2005-2007**	**CAGR 2008-2010**	**Forecast CAGR 2011-2020**	**CAGR 2005-2007**	**CAGR 2008-2010**	**Forecast CAGR 2011-2020**	**Long-term growth 2020-2055**
France	0.4%	1.8%	5.4%	1.2%	5.1%	3.5%	0.8%	9.9%	3.5%	2%
Germany	3.6%	5.2%	3%	5%	2.3%	3%	8.9%	1.8%	2.5%	2%
Italy	2.2%	-1.6%	3%	11.5%	1.4%	3%	8.9%	-1.5%	3%	2%
Spain	1.7%	12.5%	5%	8.4%	9.2%	5%	8.1%	5.2%	3%	2%
United Kingdom	2.5%	-2.5%	2%	12.3%	2.4%	5%	34.6%	-0.3%	5%	2%
EU 27	2.6%	2.9%	3%	5.5%	3.1%	3.5%	9.1%	2%	3.5%	2%

Table 3 - Yearly retail electricity prices increase
CAGR: Compound Annual Growth Rate

Wholesale peak electricity prices, which are used to estimate the prices at which the excess PV electricity is sold, are **expected to continue growing – from 3.8% to 6.7% yearly depending on the country**.

	Forecast CAGR 2011-2020
France	5.7%
Germany	6.2%
Italy	3.8%
Spain	6.6%
United Kingdom	6.7%

Table 4 - Yearly wholesale peak electricity prices increase

2.3. Methodology for generation value competitiveness – Competitiveness for utilities (ground-mounted and industrial segments)

Just like conventional electricity sources, most electricity produced by PV ground-mounted and industrial applications is consumed somewhere else. For large-scale installations, measuring PV competitiveness is a question of comparing their generation cost, not with retail electricity prices, but directly with the generation cost of electricity from competing conventional sources of electricity, such as gas.

Chapter 2 analyses the 2 following market segments on the **ability of PV electricity to compete with the generation cost of a CCGT power plant**:

- **Some industrial applications**, with systems around 500 kW
- **Utility-scale (ground-mounted) applications**, with systems around 2.5 MW

CCGT power plants are often used to deliver electricity during mid-day peaks. This puts them in direct competition with PV which is producing most of its electricity during the same period of the day.

Large ground-mounted PV installations and large-size industrial rooftops will become more attractive from an investor's point of view when they become competitive with state-of-the-art CCGT power plants.

All the assumptions used in the chapter on PV's generation cost (chapter 1) remain valid.

The assumptions taken for the CCGT power plant are summarised in Table 5.

Installed capacity (MW)	800	Efficiency of CCGT	57.4% in 2010 Additional 0.5% each year Capped at 62%
Number of hours per year	4,000		
Inflation (%)	1.5	Lifetime (years)	25
Investment cost (initial)(M €)	550	Gas prices	6.6% increase per year (IEA forecast-New policy scenario)
Production (TWh/year)	3.2		
WACC France Germany Italy Spain United Kingdom	 6.8% 6.5% 7.6% 8.2% 6.8%	CO$_2$ certificates (€/T)	2010: 20 2020: 18.2 2030: 38.4 2040: 58.5 2050: 75.2

Table 5 - CCGT power plant assumptions

3

FINDINGS: COMPETITIVENESS COULD START IN 2013

Based on the calculation of PV's generation cost in the first chapter, it is possible to make a comparison with the revenues (earnings and savings) or directly with the generation cost of a CCGT power plant as explained in the second chapter.

Figures 12A-D (page 29) show for the different segments when dynamic grid parity can be reached in Europe. Moreover, they show the comparison of PV's generation cost for industrial and ground-mounted applications with the generation cost of a CCGT power plant (generation value competitiveness).

The study assumes competitive cross-European hardware prices (modules, inverters, structural components) as well as competitive development prices (including the margins for installers). The ranges in the following figures therefore reflect the generation cost assuming mature market prices. Accordingly, the average European LCOE for 2010 and for the first half of 2011 are shown for each of the segments in these figures. This calculation considers the real market volumes and market segmentation in Europe.

Today FiTs are used to compensate for the difference in cost competitiveness between PV and conventional electricity prices. **The phase-out of those support schemes implies allowing PV electricity producers to compensate for their electricity consumption and/or selling electricity on the market**. Those revenues will come from reduced electricity bills (due to self-consumption) and the selling to utilities of the electricity not immediately consumed.

As shown earlier, the cost of generating PV electricity will decrease sharply in Europe in the coming decade whereas electricity prices in general are expected to rise. This will hasten the moment when PV becomes competitive. But for this to happen mature markets are needed; otherwise, higher prices will lead to higher generation costs and delay competitiveness.

Moreover, the dynamic evolution of all parameters, from PV system prices to electricity prices, can vary greatly in the coming years, providing at the end some moving targets for competitiveness. This should not change the final conclusion but could provide surprises in some market segments.

Even considering all of these factors, **it is clear that dynamic grid parity could occur in Italy in 2013 in the commercial segment, and then spread all across the continent in the different market segments by 2020. Generation value competitiveness could be reached as early as 2014 in the ground-mounted segment in Italy and then spread out in Europe to many additional countries by 2020**.

With different irradiance from South to North in most of the large EU countries, different market segments and electricity prices, competitiveness will not happen at exactly the same time everywhere in Europe. In Italy, where solar irradiance is higher than in Germany and so is the cost of electricity, competitiveness will arrive sooner.

In most countries, all the population will be able to benefit from PV electricity at a competitive price in a couple of years. Figure 1 (page 7) shows the number of households affected by dynamic grid parity every year (for residential systems) as well as the dates when average competitiveness can be reached.

In summary, **most major EU markets could reach competitiveness before 2020 under a mature market assumption**.

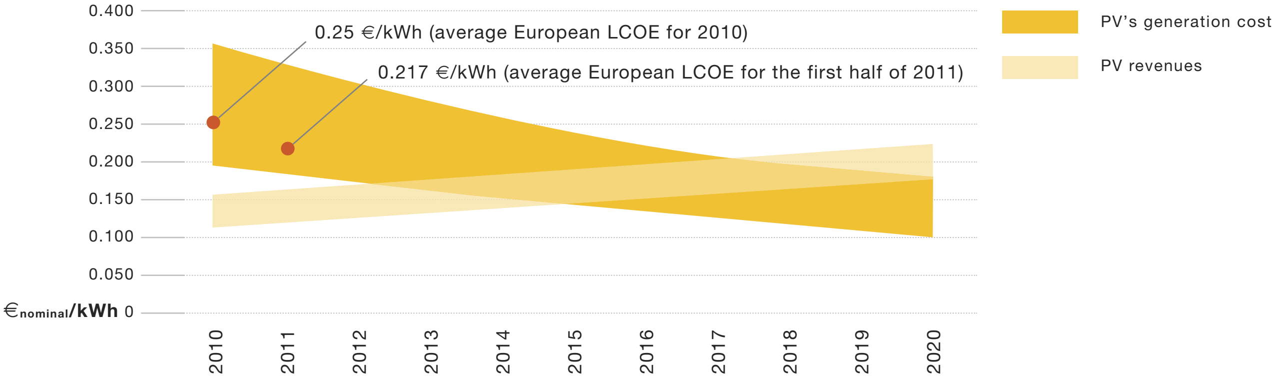


Figure 12A - Dynamic grid parity for residential PV systems in Europe

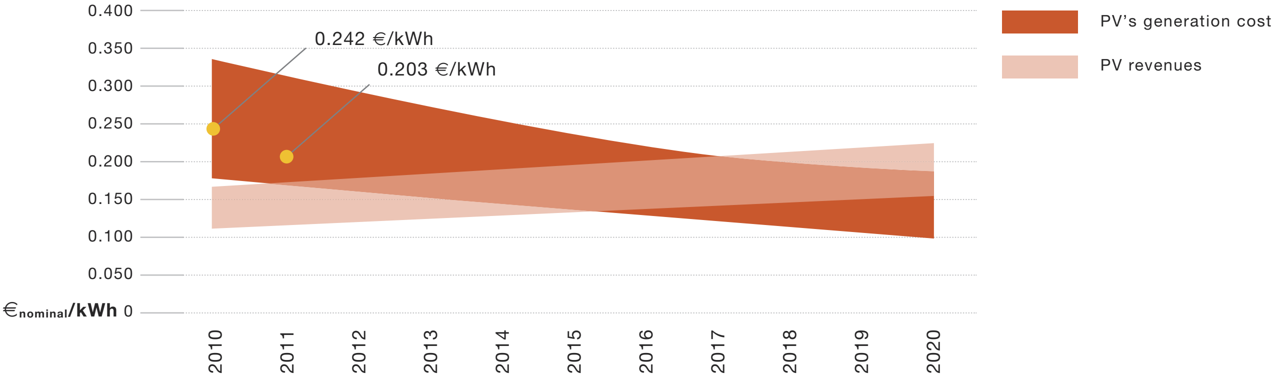


Figure 12B - Dynamic grid parity for commercial PV systems in Europe

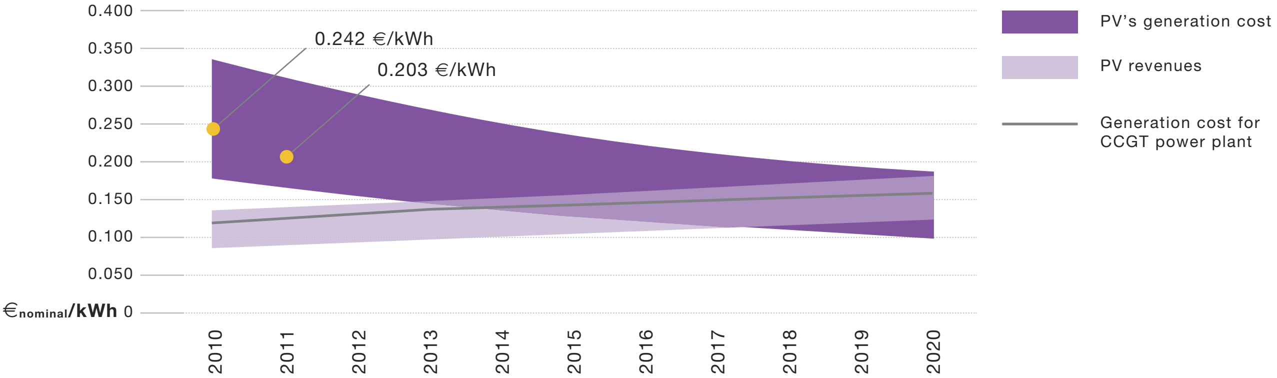


Figure 12C - Dynamic grid parity for industrial PV systems in Europe and generation value competitiveness (comparison with CCGT power plant)

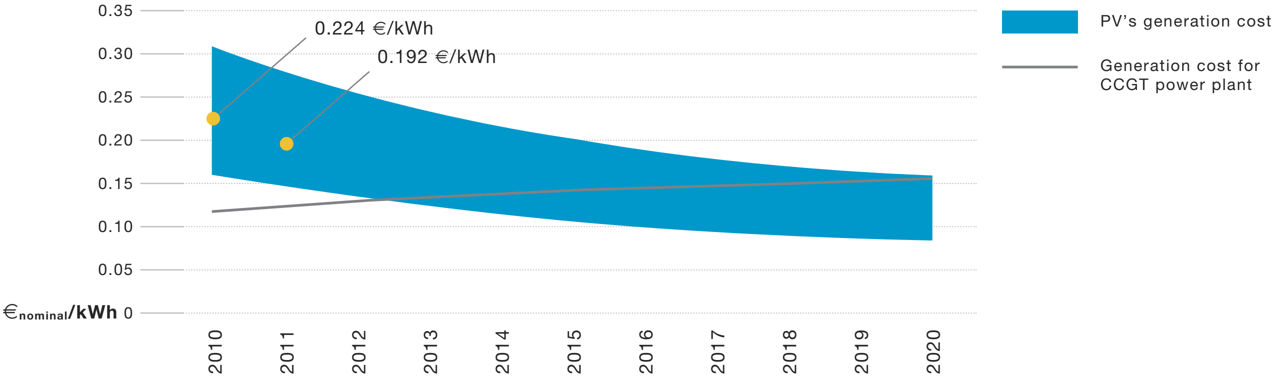


Figure 12D - Generation value competitiveness of large ground-mounted applications in Europe (comparison with CCGT power plant)

Sensitivity analysis

Reaching competitiveness will depend on the ability, country by country, to define the right policies.

What could delay competitiveness?

- The **generation cost** (LCOE) used in this report is achievable (based on real data) but unnecessary margins and local administrative costs still keep the prices artificially high in some countries.
- **Specific applications** such as BIPV on existing buildings could be more expensive and delay the parity moment.
- Some **investors are today asking for a "green premium"** above the real investor's risk. This could delay competitiveness by, on average, one year in most market segments.

What could accelerate competitiveness?

- An unexpected **surge in fossil fuel prices** could lead to a rapid increase of electricity prices.
- The **self-consumption** case used for "prosumers" is rather conservative. All other net-metering schemes or systems that would pay higher prices for electricity injected in the grid or that could allow for a partial refund of grid costs (as it exists today in Italy) would increase PV revenues.
- **BIPV applications on new or renovated roofs** can reduce system prices.
- Solar irradiance factors in a country: a part of the country will reach competitiveness sooner than the average value.

4

POLICY RECOMMENDATIONS

PV system prices have gone down by 50% in the last 5 years and will continue to decrease in the coming decade. This will lead PV's generation cost to go down while the cost of electricity in general goes up. As a result, **PV will be able to reach full competitiveness with grid electricity (defined as dynamic grid parity) as early as 2013 in the commercial segment in Italy and before 2020 for all market segments** (in countries with mature markets and efficient support schemes). But this will also depend on certain conditions being met.

The "Photovoltaic Observatory" publication (EPIA, 2011) provides a comprehensive and detailed view of policy recommendations for the sustainable development of PV markets. This document is available at www.epia.org/publications.

Achieving competitiveness

The decreases in system prices and accordingly in generation costs are feasible from a combined technological and market deployment point of view. But in some countries market distortions keep PV system prices artificially high. In order to remove those distorting factors and achieve full PV competitiveness, and also to boost investors' confidence in PV technology, political commitment to the following priorities is essential:

- The **market must continue to grow in a sustainable way**. Any hindrance of market growth, both in and outside Europe, will slow the price decrease and delay competitiveness.
- **Market development must occur in all countries and all market segments**. This will trigger the development of a dense network of trained and certified installers which will decrease the cost of installation and construction, create sustainable and competitive margins for all players in the PV industry and accelerate cost decrease because of scaling and learning effects.
- **Support schemes (including FiTs) need to be adapted** on a regular basis to avoid market disturbance. Profitability can be assessed on a regular basis and support schemes adapted accordingly.
- **Administrative barriers must be removed** and procedures streamlined so that additional costs do not increase total PV system prices.
- **Grid connections must be simple and easily authorised,** and priority access to the grid for PV electricity should be ensured.
- **Political commitment to continuous research and development must be assured**, so that PV technology continues to develop. Innovation will lead to increased efficiency and accelerate competitiveness.
- **PV should be considered a low-risk investment**; therefore **reasonable profits should be taken in line with that risk level**. Investors should look at the real risk associated with the installation and exploitation of PV systems to ensure easy access to inexpensive financing.

Competitiveness and beyond

Smart deployment of support mechanisms, such as FiTs, has helped PV gain a market foothold in many countries of the world, compensating for the difference in cost competitiveness between PV electricity and that of conventional sources. As that competitiveness gap narrows for the PV sector, due to technology development and parallel decrease of generation cost, PV will be able to rely progressively less on dedicated financial support, leading to the phasing out of such support schemes. But achieving competitiveness should not mean the end of all incentives; current support mechanisms could, depending on the segment considered, be replaced by more indirect and time-limited incentives.

This phasing out of support schemes will happen even quicker if internalisation of external effects is implemented for all technologies and subsidies to other energy sources are also phased out, leading to a truly level playing field.

Once such a framework is established, policymakers should consider the following options in the residential, commercial and industrial segments:

- **Put in place mechanisms that will help close the gap and cover the high up-front investment**: fiscal incentives such as tax rebates, reduced VAT and zero/low interest long-term guaranteed loans might be relevant if tailored to national specificities.

- **Allow final customers to sell the electricity produced on the market**: final customers should have access to real-time production and consumption data. This information should be made available to a third party acting on their behalf in order to develop the role of energy aggregators.
- **Maximise savings on the electricity bill**: these will be directly linked to the avoided cost of electricity by using the PV power produced on-site. Regulatory frameworks should therefore promote net-metering and self-consumption schemes. In addition, electricity tariffs designed for time-dependent charges will play an important role, together with new technologies enabling more on-site consumption.

In the utility-scale segment, the framework market conditions will play a key role in driving investments in PV. The goals should be to:

- **Facilitate access to capital** by lowering the perceived risk.
- **Emphasise the long-term stability of policies and the availability of sizeable unconstrained volume** for deployment combined with access to financial instruments and financing funds.

Finally, PV competitiveness is likely to come first to specific market segments and specific locations, not necessarily to whole countries. This means:

- **Some specific incentives might still be needed** for a couple of years in order to ensure PV competitiveness in Northern regions of a country.
- **Dedicated support mechanisms could be required on a temporary basis for more specific technologies,** such as residential and commercial BIPV, or innovative current and upcoming technologies such as concentrated solar PV, organic PV and dye-sensitised solar cells.
- **Grid stability could be favoured through new incentives** for decentralised storage or demand side management, or to provide additional network services contributing to network stability.

CONCLUSION

PV competitiveness is coming soon - and sooner than many people think. Many factors – from market segments, regional variations in solar irradiance and national differences in legal and administrative procedures to the effectiveness and adaptability of support schemes – will influence the moment when competitiveness is achieved. This study has considered several possible scenarios. The most realistic assumptions were chosen to assess when full competitiveness will be reached. But under even more favourable conditions than the ones outlined above, PV competitiveness could occur sooner than predicted.

One thing is clear in all of the scenarios: when it comes to the growing PV competitiveness, the defining issue is not price, which has been coming down for years and will continue to do so under almost all circumstances. The PV industry is fully committed to further decrease the price should European governments make the right political choices. PV is one of the world's most promising energy sources and is on the way to competing in the energy sector.

Contributions:

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Irradiance data has been derived from SolarGIS database: http://solargis.info (©2011 GeoModel Solar).

Cost of administrative barriers and grid connections are derived from the PV Legal project: www.pvlegal.eu

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