d. Third generation photovoltaics

After more than 20 years of research and development, third generation solar devices are beginning to emerge in the marketplace.

Many of the new technologies are very promising. One exciting development is organic PV cells. These include both fully organic PV (OPV) solar cells and the hybrid dye-sensitised solar cells (DSSC).

Suppliers of OPV produced 5 MW of solar cells in 2009. They are moving towards full commercialisation and have announced plans to increase production to more than 1 GW by 2012. Current cell efficiencies are about 6% for very small areas and below 4% for larger areas.

Manufacturers of DSSC produced about 30 MW of solar cells in 2009. By 2012, 200 MW are expected to be produced. In 2009, some low-power applications were already commercially available. Efficiencies achieved at the lab across a very small area are in the range of 8 to 12%. Commercial applications still have efficiency below 4%.

For both technologies, manufacturing costs is constantly decreasing and is expected to reach 0.50€/W by 2020. This is enabled by the use of the R2R manufacturing process and standard printing technologies. The major challenges for this sector are the low device efficiency and their instability in the long-term.

Third generation technologies that are beginning to reach the market are called "emerging" and can be classified as:

- Advanced inorganic Thin Films such as spherical CIS and Thin-Film polycrystalline silicon solar cells.
- Organic solar cells which include both fully organic and hybrid dye-sensitised solar cells.
- Thermo-photovoltaic (TPV) low band-gap cells which can be used in combined heat and power (CHP) systems.

Third generation PV products have a significant competitive advantage in consumer applications because of the substrate flexibility and ability to perform in dim or variable lighting conditions. Possible application areas include low-power consumer electronics (such as mobile phone rechargers, lighting applications and self-powered displays), outdoor recreational applications, and BIPV.

"Third generation solar devices are beginning to emerge in the market-place."

In addition to the emerging third generation PV technologies mentioned, a number of novel technologies are also under development:

- Active layers can be created by introducing quantum dots or nanotechnology particles. This technology is likely to be used in concentrator devices.
- Tailoring the solar spectrum to wavelengths with maximum collection efficiency or increasing the absorption level of the solar cell. These adjustments can be applied to all existing solar cell technologies.

Table 7 shows the efficiency ranges of currently available commercial technologies. The area that needs to be covered to generate 1 kWp is also shown.

TABLE 7
OVERVIEW OF COMMERCIAL PV TECHNOLOGIES

Commercial Module Efficiency

Technology	Thin Film					Crystalline Silicon		CPV
	(a-Si)	(CdTe)	CI(G)S	a-Si/µc-Si	Dye s. cells	Mono	Multi	III-V Multi-junction
Cell efficiency	4-8%	10-11%	7-12%	7-9%	2-4%	16-22%	14-18%	30-38%
Module efficiency						13-19%	11-15%	~25%
Area needed per KW (for modules)	~15m²	~10m²	~10m²	~12m²		~7m²	~8m²	

source: EPIA 2010. Photon International, March 2010, EPIA analysis. Efficiency based on Standard Test conditions.

e. Historical and future evolution

Crystalline silicon technologies have dominated the market for the last 30 years. Amorphous silicon (a-Si) has been the technology most used for consumer applications (e.g. calculators, solar watches) due to its lower manufacturing cost while c-Si technologies have been used mainly in both stand-alone and on-grid systems.

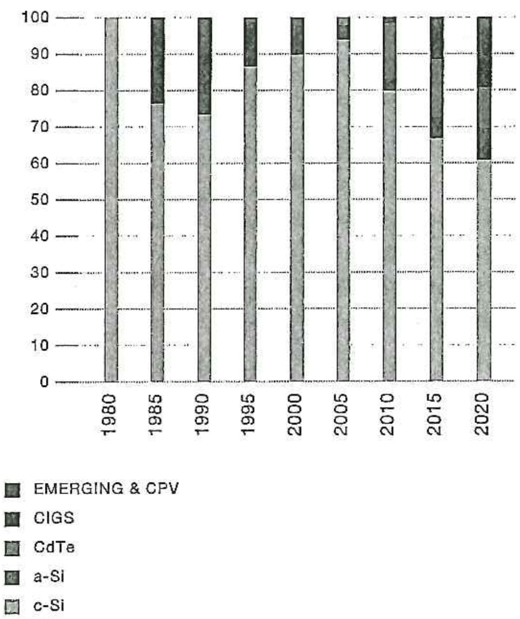
Within the c-Si technologies, mono- and multi-crystalline cells are produced in fairly equal proportion. However, multi-crystalline cells are gaining market share. Ribbon c-Si represents less than 5% of the market.

While a-Si has been the preferred clear Thin-Film technology used over the past three decades, its market share has decreased significantly compared to more advanced and competitive technologies. For example, CdTe has grown from a 2% market share in 2005 to 13% in 2010.

Technologies such as Concentrator PV (CPV), organics and dye-sensitised solar cells are beginning to enter the market. They are expected to achieve significant market share in the next few years, capturing around 5% of the market by 2020.

EPIA expects that by 2020 silicon wafer-based technologies will account for about 61% of sales, while Thin Films will account for around 33%. CPV and emerging technologies will account for the remaining 6%.

FIGURE 12
HISTORICAL EVOLUTION OF TECHNOLOGY MARKET SHARE AND FUTURE TRENDS
%



source: Historical data (until 2009) based on Navigant Consulting, Estimations based on EPIA analysis.

2.3. The PV value chain

The PV value chain is typically divided into a number of upstream and downstream activities.

a. The upstream part of the value chain

Upstream activities include all steps from the manufacturing of equipment and materials to the production of modules, inverters and other balance of system (BOS) elements. Supply of certain materials and equipment is concentrated in the hands of a few very large players. For example:

- About 75 companies are active in polysilicon production. However, in 2009, more than 90% of the total supply was manufactured by seven major players from Europe, the USA and Japan. Nowadays many Chinese companies are ramping-up capacity and are expected to account for a larger share of the polysilicon market over the next few years[5].
- The market is more segmented and competitive in the area of wafer and cell manufacturing. More than 200 companies are active in this sector. Around 1,000 companies produced c-Si modules in 2010.
- Also with respect to inverter production, the top ten companies produce more than 80% of the inverters sold on the market, even though there are more than 300 companies active in this segment.
- In the case of Thin Film module manufacturing, about 160 companies are active. About 130 of these companies produce silicon-based Thin Films. Around 30 produce CIGS/CIS Thin Films, while a handful of companies are active in CdTe.
- There are currently more than 50 companies that offer turnkey c-Si production lines. Less than 30 manufacturers provide the PV industry with Thin Film production lines[6].

TABLE 8
NUMBER OF COMPANIES WORLD-WIDE IN THE THIN FILM VALUE CHAIN

	CdTe	a-Si	a-Si/μ-Si	CI(G)S
Number of companies (as of 2009)	4	131		30
Production in 2009	1,100 MW	< 300 MW	< 400 MW	< 200 MW

source: Energy Focus, Photon, JRC and EPIA.

TABLE 9
NUMBER OF COMPANIES WORLD-WIDE IN THE CRYSTALLINE SILICON VALUE CHAIN
2009

2009	SILICON	INGOTS / WAFERS	CELLS	MODULES
Number of companies:	75	208	239	988
Production capacity:	130,000 TONNES	15,000 MW	18,000 MW	19,000 MW
Effective production:	90,000 TONNES	10,000 MW	9,000 MW	7,000 MW

source: ENergy Focus, Photon, JRC and EPIA.

b. The downstream part of the value chain

The downstream part of the value chain includes:

- Wholesalers who function as intermediaries between the manufacturers and the installer or end customer.
- System developers who offer their services in building turnkey PV installations.
- Owners of PV installations that sell their power to the grid.

"The consolidation of the PV sector is likely to end the current fragmentation and facilitate the emergence of larger industry players."

Many small to medium enterprises (SMEs) are involved in these activities and most are locally organised. As such, this part of the value chain is very fragmented and difficult to track.

The engineering, procurement and construction (EPC) companies involved in the development of PV systems are experienced in obtaining finance, selecting the correct components and advising on a suitable location and system design. Most are familiar with local legal, administrative and grid connection requirements. They can guide the PV system owner through the different types of support mechanisms. EPC companies also physically install the PV system using either internal personnel or qualified subcontractors. As a result of the latest technological developments in BIPV and CPV, some developers have developed specific expertise and are now specialising in these areas.

PV systems have a typical lifespan of at least 25 years. At the end of its life, the system is decommissioned and the modules are recycled. In Europe, the PV CYCLE association established a voluntary take back scheme with established already a large number of collection points in different EU countries where PV modules are collected are sent to specialised PV recycling facilities for recycling. The recycled materials (such as glass, aluminium, semiconductor materials, ...) can then be re-used for the production of PV or other products. For more information about PV CYCLE, see Solar benefits and sustainability in part 6[7].

c. Consolidation trends in the solar industry

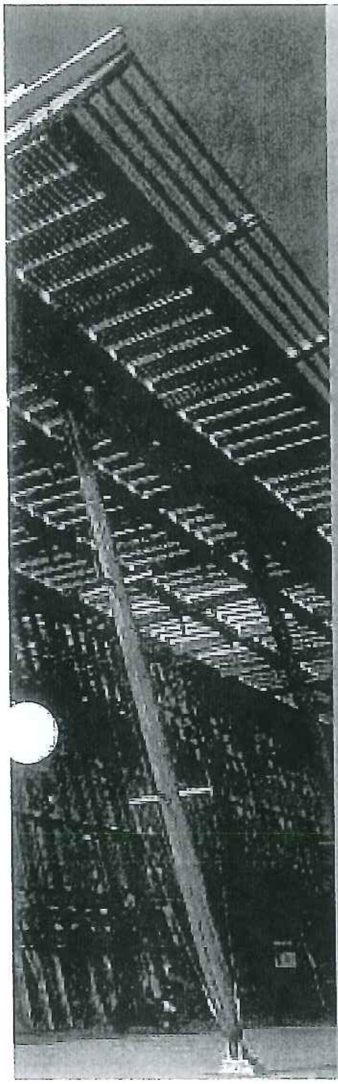
For many years, most companies have grown by specialising in a single activity within the value chain (especially in the case of c-Si technologies). These companies are known as "pure players". However, there has been an increasing tendency to integrate additional production steps into the same company. Known as "integrated players", these companies cover a number of activities ranging from silicon to module production. Companies that cover all steps in the process are known as "fully integrated players". Both approaches present benefits and drawbacks. On the one hand, the "pure players" may be more competitive in their core activity, but they can be highly dependent on standardisation efforts and their suppliers. The "integrated players" on the other hand have more security over their supply chain and are generally more flexible financially. However, their research and development expenditure cannot be affected to one specific part of the value chain.

While some of the top polysilicon producers are still pure players, many are also moving into the wafer production business. Most cell manufacturers secure sales through the production of modules. Today, many large c-Si PV companies are integrated players and some have, or intend to, become fully integrated. The Thin Film manufacturing sector is not segmented to the same extent as the entire manufacturing process is normally carried out at a single facility.

Integration does not only occur in the upstream part of the value chain. About 30% of module manufacturers are currently active in the development of complete PV systems.* Moreover, some system developers are also starting to own systems and sell electricity to grid operators. This is known as the utility concept and the business model is gaining support. This is especially true in the US, where an increasing number of module producers are entering the electricity generation market.

In recent years there have been a number of mergers and acquisitions amongst PV companies. A total of 61 such transactions were reported in the solar industry between July 2008 and March 2009[8]. This consolidation is likely to end the current fragmentation of the solar PV market and facilitate the emergence of larger industry players. Companies having large production capacities at their disposal will benefit from the consequent economies of scale. This will result into a further decrease of the manufacturing costs.

* This calculation is based on the membership of EPIA, which can be considered as a representative sample of all the players in the PV industry.



SOLAR COST AND COMPETITIVENESS: TOWARDS GRID PARITY 3

3. SOLAR COST AND COMPETITIVENESS: TOWARDS GRID PARITY

The cost of PV systems has been constantly decreasing over time. Grid parity (traditionally defined as the point in time where the generation cost of solar PV electricity equals the cost of conventional electricity sources) is already achieved for some specific applications in some parts of the world. Competitiveness is just around the corner.

"Over the past 30 years the PV industry has achieved impressive price decreases."

This section outlines the factors that will affect the PV industry's ability to achieve competitiveness with conventional electricity producers and retail electricity prices.

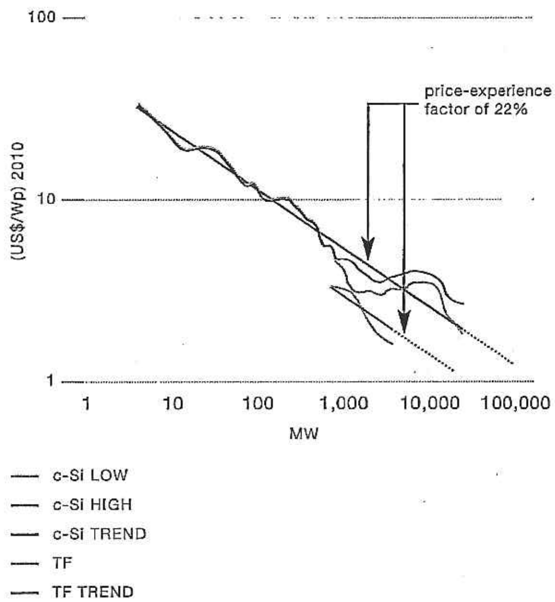
3.1. Price competitiveness of PV

a. PV module price

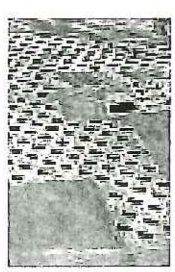
Over the past 30 years the PV industry has achieved impressive price decreases. The price of PV modules has reduced by 22% each time the cumulative installed capacity (in MW) has doubled (see Figure 13).

The decrease in manufacturing costs and retail prices of PV modules and systems (including electronics and safety devices, cabling, mounting structures, and installation) have come as the industry has gained from economies of scale and experience. This has been brought about by extensive innovation, research, development and ongoing political support for the development of the PV market.

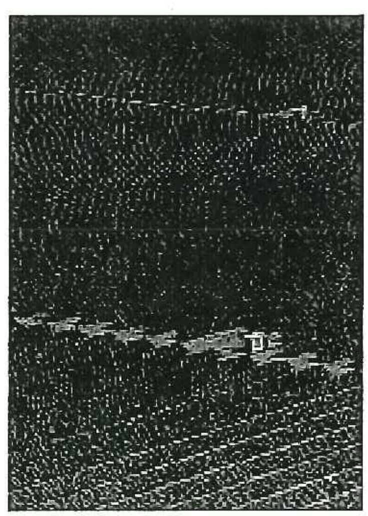
FIGURE 13
PV MODULE PRICE EXPERIENCE CURVE
US$/Wp & MW



source: Navigant Consulting, EPIA.



Large ground-mounted PV system in Spain.



Large ground-mounted PV system in Spain.

b. PV system price

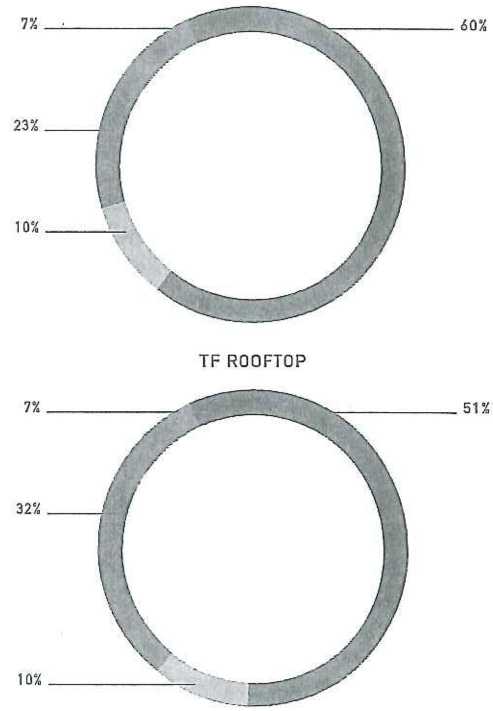
As explained above, the price of PV modules has decreased substantially over the past 30 years. The price of inverters has followed a similar price learning curve to that of PV modules. Prices for some balance of systems (BOS) elements have not decreased with the same pace. The price of the raw materials used in these elements (typically copper, steel and stainless steel) has been more volatile. Installation costs have decreased at different rates depending on the maturity of the market and type of application. For example, some mounting structures designed for specific types of installations (such as BIPV) can be installed in half the time it takes to install a more complex version. This of course lowers the total installation costs.

Reductions in prices for materials (such as mounting structures), cables, land use and installation account for much of the decrease in BOS costs. Another contributor to the decrease of BOS and installation-related costs is the increase in efficiency at module level. More efficient modules imply lower costs for balance of system equipment, installation-related costs and land use.

Figure 14 shows as an example the price structure of PV systems for small rooftop (3 kWp) installations in mature markets. In only 5 years time, the share of the PV modules in the total system price has fallen from about 60-75% to as low as 40-60%, depending on the technology. The inverter accounts for roughly 10% of the total system price. The cost of engineering and procurement makes up about 7% of the total system price. The remaining costs represent the other balance of system components and the cost of installation.

The forecasts for prices of large PV systems are summarised in Figure 15. In 2010, the range represents prices for large systems in Germany. The rate at which PV system prices will decrease depends on the installed PV capacity. By 2030 prices could drop to between €0.70/Wp to €0.93/Wp. By 2050, the price could be even as low as €0.56/Wp.

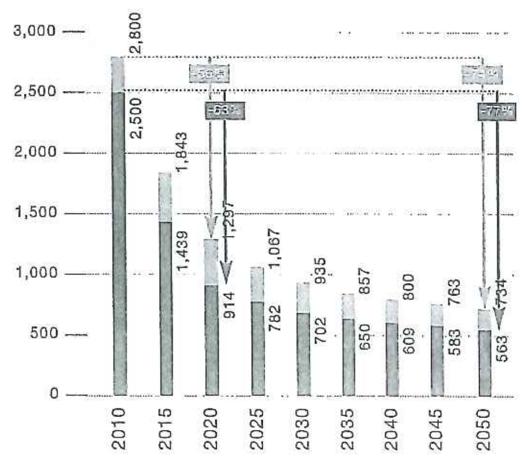
FIGURE 14
COSTS OF PV SYSTEM ELEMENTS
%



MODULE PRICE
INVERTER PRICE
BOS+INSTALLATION
ENGINEERING & PROCUREMENT

source: EPIA, EuPD, Navigant Consulting, Photon Consulting, SolarBuzz.
note: Values based on mature markets.

FIGURE 15
EVOLUTION OF PRICES OF LARGE PV SYSTEMS
€/KWp



ACCELERATED SCENARIO
PARADIGM SHIFT SCENARIO

source: Greenpeace/EPIA Solar generation VI 2010.

"By 2030 prices could drop to between €0.70/Wp to €0.93/Wp."

c. PV electricity generation cost

The indicator used to compare the cost of PV electricity with other sources of electricity generation is the cost per kilowatt hour (kWh). The Levelised Cost of Electricity (LCOE) is a measurement tool that is used to compare different power generation plants. It 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 a power plant utilising a gas or nuclear fuel source. Each system has very different lifetimes and investment costs which are taken into account for the LCOE calculation. The LCOE takes this into account. Moreover, for PV systems, the LCOE considers the location of the system and the annual irradiation. For example, Scandinavia typically receives 1,000 kWh/m² of sunlight. In southern Europe the irradiation can go over 1,900 kWh/m², while in the Middle East and in sub-Saharan Africa sunlight irradiation can reach up to 2,200 kWh/m².

"Expected generation costs for large, ground-mounted PV systems in 2020 are in the range of €0.07 to €0.17/kWh across Europe.

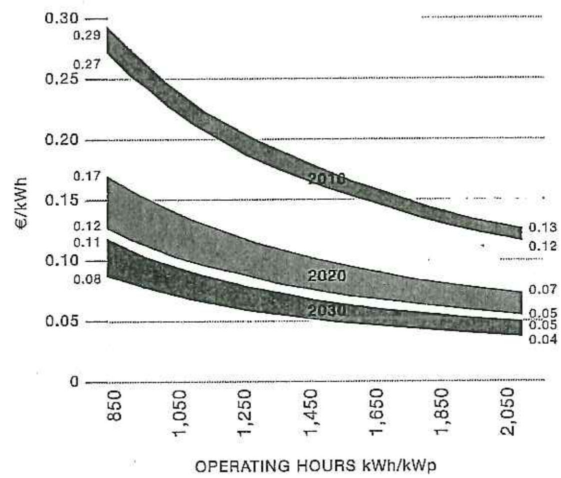
Figure 16 shows current PV electricity generation costs for large ground-mounted systems. The data is based on the most competitive turnkey system price and a typical system performance ratio (the amount of kWh that can be produced per kWp installed) of 85%.

For large ground-mounted systems, the generation costs in 2010 range from around €0.29/kWh in the north of Europe to €0.15/kWh in the south and as low as €0.12/kWh in the Middle East.

According to EPIA estimations those rates will fall significantly over the next decade. Expected generation costs for large, ground-mounted PV systems in 2020 are in the range of €0.07 to €0.17/kWh across Europe. In the sunniest Sunbelt countries the rate could be as low as €0.04/kWh by 2030.

EPIA forecasts that prices for residential PV systems and the associated LCOE will also decrease strongly over the next 20 years. However, they will remain more expensive than large ground-mounted systems.

FIGURE 16
LEVELISED COST OF ELECTRICITY (LCOE)
€/KWh



source: Greenpeace/EPIA Solar generation VI 2010.

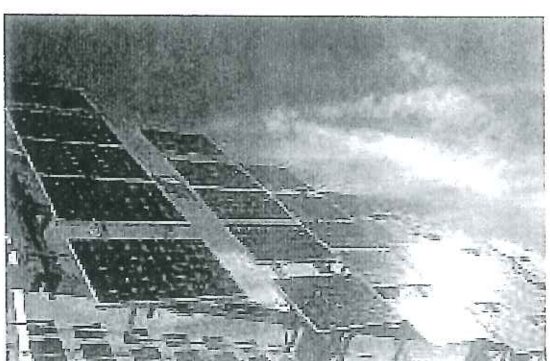
d. Electricity price evolution

Costs for the electricity generated in existing gas and coal-fired power plants are constantly rising. This is a real driver for the full competitiveness of PV. Energy prices are increasing in many regions of the world due to the nature of the current energy mix. The use of finite resources for power generation (such as oil, gas, coal and uranium), in addition togrowing economic and environmental costs will lead to increased price for energy generated from fossil and nuclear fuels.

An unfair advantage

Conventional electricity prices do not reflect actual production costs. Many governments still subsidise the coal industry and promote the use of locally-produced coal through specific incentives. The European Union invests more in nuclear energy research (€540 million yearly in average over five years through the EURATOM treaty) than in research for all renewable energy sources, smart grids and energy efficiency measures combined (€335 million yearly in average over seven years through the Seventh framework program). Actually today in Europe, fossil fuels and nuclear power are still receiving four times the level of subsidies that all types of renewable energies do[9].*

Given the strong financial and political backing for conventional sources of electricity over several decades, it is reasonable to expect continuing financial support for renewable energy sources, such as wind and solar, until they are fully competitive.



PV power plant in Darro, Spain.

External costs of conventional electricity generation

The external costs to society incurred from burning fossil fuels or nuclear power generation are not currently included in most electricity prices. These costs are both local and, in the case of climate change, global. As there is uncertainty about the magnitude of these costs, they are difficult to quantify and include in the electricity prices.

The market price of CO_2 certificates remains quite low (around €14/tonne CO_2 end of 2010)[10] but is expected to rise in the coming decades.

"Conventional electricity prices do not reflect actual production costs."

On the other side, the real cost of CO_2 was calculated at €70/tonne CO_2 from 2010 to 2050[11].

Other studies consider even higher CO_2 costs, up to US$160/tonne CO_2[12].

Taking a conservative approach, the cost of carbon dioxide emissions from fossil fuels could be in the range of US$10 to US$20/tonne CO_2. PV reduces emissions of CO_2 by an average of 0.6 kg/kWh. The resulting average cost avoided for every kWh produced by solar energy will therefore be in the range of US$0.006 to US$0.012/kWh.

The *Stern Review on the Economics of Climate Change*, published by the UK government in 2006, concluded that any investment made now to reduce CO_2 emissions will be paid back in the future as the external costs of fossil fuel consumption will be avoided.

* Globally, the IEA has recently estimated fossil fuel subsidies at US$312bn. The European Energy Association: EEA Technical report 1/2004 (the most recent figures for the EU (EU15)) put fossil fuel subsidies at €21.7bn compared to €5.3bn for renewable energy.

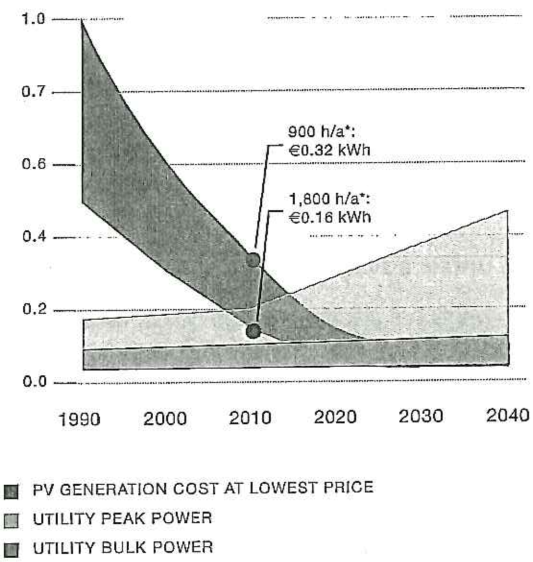
"In many countries with high electricity prices and high sun irradiation, the competitiveness of PV for residential consumers could already be achieved with low PV system costs and the simplification of administrative procedures."

PV generation cost is decreasing, electricity prices are increasing

In many countries with high electricity prices and high Sun irradiation, the competitiveness of PV for residential systems could already be achieved with low PV system costs and the simplification of administrative procedures.

Figure 17 shows the historical development and future trends of retail electricity prices compared to the cost of PV electricity. The upper and lower parts of the PV curve represent northern Europe and southern of Europe respectively. The utility prices for electricity are split into peak power prices (usually during the day) and bulk power. In southern Europe, solar electricity is already or will become cost-competitive with peak power within the next few years. Areas with less irradiation, such as central Europe, will reach this point before 2020. The trend is similar for most regions world-wide. For example, in developing countries electricity prices are rising due to higher demand whereas PV electricity generation cost is already low and PV often more cost-competitive.

FIGURE 17
DEVELOPMENT OF UTILITY PRICES AND PV GENERATION COSTS
€/KWh



*h/a: Hours of sun per annum. 900 h/a corresponds to northern countries of Europe. 1,800 h/a corresponds to southern countries of Europe.

source: EPIA.

e. Market segments for PV

PV consumer applications do not benefit from any support mechanism and have been on the market for many years. They have already proven their competitiveness. Consumer applications provide improved convenience, and often replace environmentally non friendly batteries.

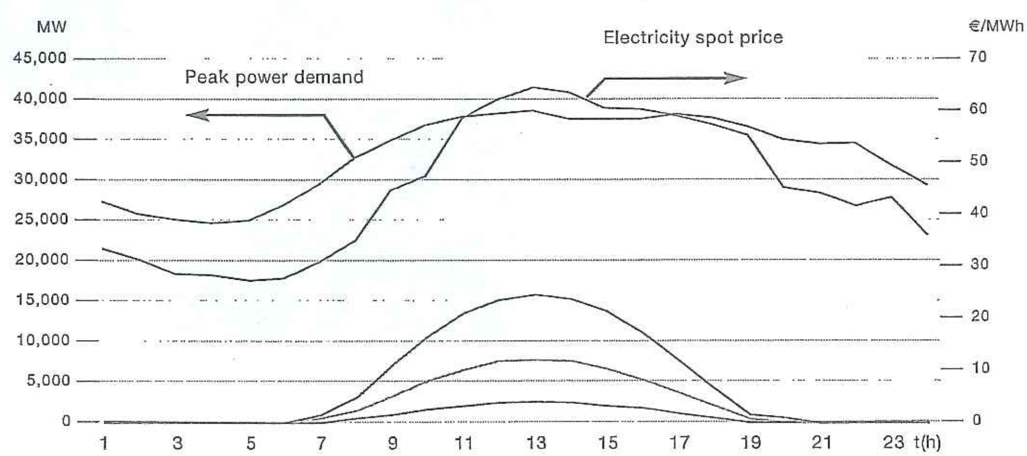
Off-grid applications are already cost-competitive compared to diesel generators, which have high fuel costs, or the extension of the electricity grid, which requires a considerable investment.

Grid-connected applications are not yet competitive everywhere. A distinction must be made between decentralised residential applications and the more centralised utility-scale ground-mounted systems.

Large utility-scale PV systems provide electricity at a price that cannot be directly compared with residential electricity prices but with the cost of conventional (centralised) sources of electricity. The electricity generated in a large PV system is not consumed directly, but sold on the electricity spot market where it competes directly with other sources of electricity. The evolution of prices on the spot market is linked to supply and demand factors. These prices are also closely related to the energy mix currently used for power generation.

The competitiveness of large-scale PV systems will then be reached when the cumulative benefit of selling PV electricity on spot markets matches that of conventional electricity sources over the course of a full year. In sunny countries, PV can compete during the midday peak when gas powered plants or specific peak-generation devices are used. Figure 18 shows three scenarios for the deployment of PV electricity, the electricity demand and electricity spot price in .Spain during the summer. It clearly shows that PV produces electricity during moments of peak demand when the spot prices are the highest.

FIGURE 18
PEAK LOAD DEMAND AND ELECTRICITY SPOT PRICE IN SPAIN ON 18 JULY 2007



PV INSTALLED: 20,000 MWp
PV INSTALLED: 10,000 MWp
PV INSTALLED: 3,137 MWp (REAL CAPACITY INSTALLED IN SPAIN IN 2008)

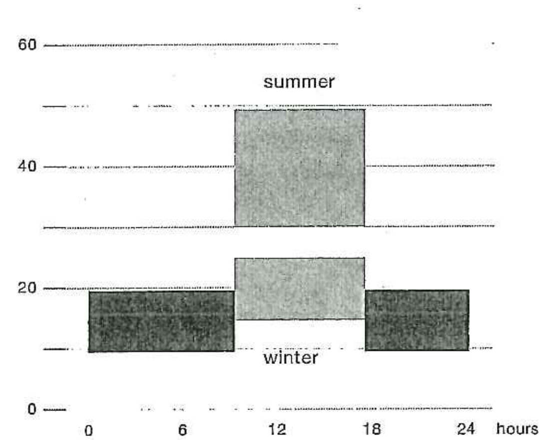
source: OMEL/UCTE. Sunrise project based on measured data.

For the residential segment, EUROSTAT estimates electricity prices in the EU-27 were in the range of €0.09 and €0.27/kWh (including taxes) during the second half of 2010. This is lower than the cost of generating PV electricity. However, in 2010 the average household electricity price in Europe was 5% higher than in the second half of 2007. As a comparison, between 2007 and 2009, the cost of PV electricity dropped by almost 40% to an average of €0.22/kWh.

Care must be taken when comparing the cost of PV electricity across larger regions as there might be huge differences between countries and even within the same country. In some countries, electricity prices are more responsive to demand peaks. In California, Japan and some EU countries, electricity prices increase substantially during the day. This is particularly true in the summer, as demand for electricity is the highest during this period. In other countries, the electricity prices are the highest during winter periods.

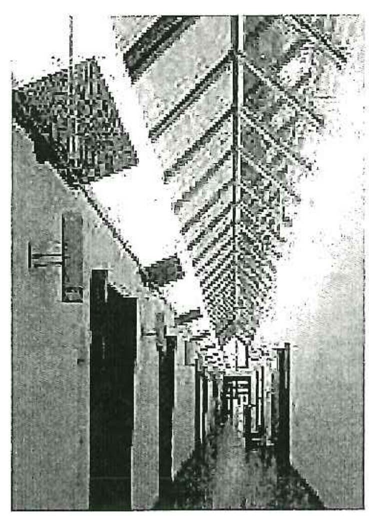
In California however where during the summer days the electricity price is substantially higher than during winter, PV is already competitive during these summer peaks. The summer is also the period when the electricity output of PV systems is at its highest. PV therefore serves the market at exactly the point when demand is the greatest. Figure 19 shows the significant variation between regular and peak prices for household electricity in the Californian market.

FIGURE 19
RANGE OF HOUSEHOLD ELECTRICITY PRICES IN CALIFORNIA
$ct/kWh



LOW CONSUMPTION PERIOD
PEAK CONSUMPTION PERIOD

source: Hyde, BSW-Solar, 2006.



Glass roof, a-si amorphous silicon thin film integrated in glass.

Workers installing PV modules.

3.2. Factors affecting PV system cost reduction

The solar industry is constantly innovating in order to improve products efficiency and make materials use more environmentally friendly. However, the cost of PV systems also needs to be reduced to make them competitive with conventional sources of electricity. EPIA believes this can be achieved through:

- Technological innovation
- Production optimisation
- Economies of scale
- Increased performance ratio of PV
- Extended lifetime of PV systems
- Development of standards and specifications.

a. Technological innovation

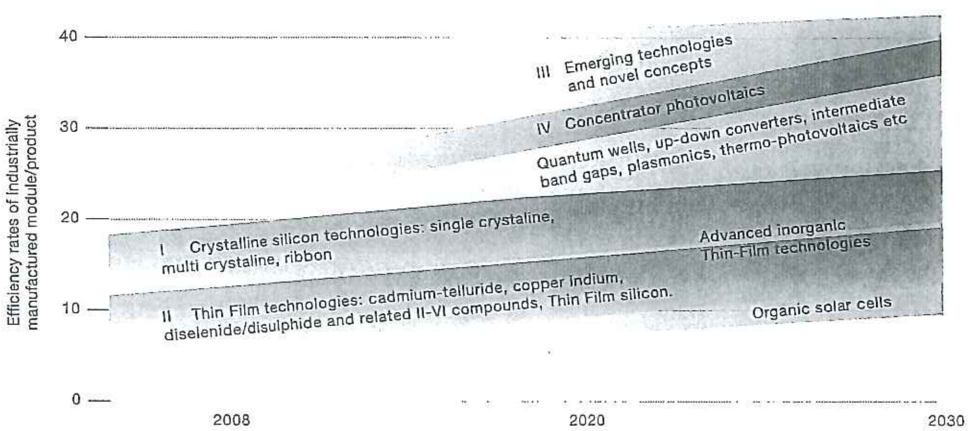
One of the main ways the industry can reduce manufacturing and electricity generation costs is through efficiency. When PV modules are more efficient, they use less material (such as active layers, aluminium frames, glass and other substrates). This requires less energy for manufacturing and also lowers the balance of system (BOS) costs. With higher-efficiency modules, less surface area is needed. This reduces the need for mounting structures, cables, and other components. All of these savings affect the final generation cost.

However, efficiency is not the only factor that needs to be studied. The PV sector has a primary goal to introduce more environmentally friendly materials to replace scarce resources such as silver, indium and tellurium, and materials such as lead and cadmium. Lead-free solar cells are already available in the market. However, a number of manufacturers claim that by 2012 the cells are expected to be lead-free without performance losses. Alternatives to silver will be on the market by 2013 to 2015[13].

Another key area of research aims to reduce material usage and energy requirements. The PV sector is working to reduce costs and energy payback times by using thinner wafers (see Table 9), more efficient wafers, and polysilicon substitutes (for example, upgraded metallurgical silicon). In the field of Thin Film technologies the top priorities are to increase the substrate areas and depositions speeds while keeping material uniformity.

"The cost of PV systems needs to be reduced to make them competitive with conventional sources of electricity."

FIGURE 20
PHOTOVOLTAIC TECHNOLOGY STATUS AND PROSPECTS
%



source: IEA PVPS.

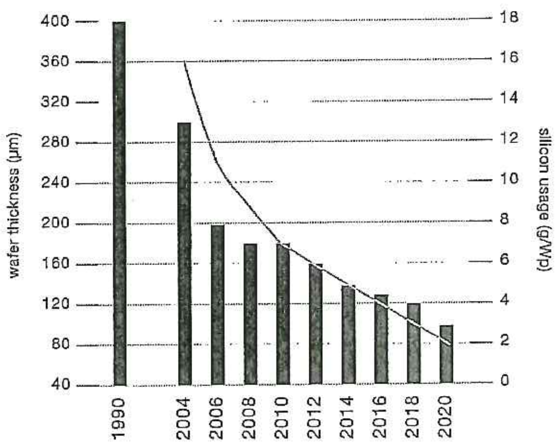
Wafer thickness and dimension

A good example of technology evolution is the wafer dimension. The method of producing the wafers needs to be modified so that thinner and larger wafers can be handled. This requires changes to the cell process and the technology used to build the module. For example, the contacts will probably need to be moved to the back of the cell. Larger solar cells require modifications to other system components such as the inverter.

Wafer thickness is expected to be reduced from 180 to 200 µm today, to less than 100 µm by 2020. Reducing wafer thickness and kerf losses also reduces silicon usage. Currently solar cell manufacturing techniques use about 7 g/W of silicon. This could drop to less than 3 g/W by 2020 (see Figure 21). Larger wafer sizes are expected from about 2015.

"Capacity increases, combined with technological innovation and manufacturing optimisation, have radically reduced the cost per unit."

FIGURE 21
c-Si SOLAR CELL DEVELOPMENT
wafer thickness in µm & silicon usage in g/Wp



source: EU PV Technology Platform Strategic Research Agenda, C-Si Roadmap ITPV, EPIA roadmap 2004.

b. Production optimisation

As companies scale-up production, they use more automation and larger line capacities. Improved production processes can also reduce wafer breakage and line downtime (periods of time when the production line is stopped for maintenance or optimisation). Production efficiency improvements enable the industry to reduce the costs of solar power modules.

c. Economies of scale

As with all manufacturing industries, producing more products lowers the cost per unit. Economies of scale can be achieved at the following supply and production stages:

- Bulk buying of raw materials
- Obtaining more favourable interest rates for financing
- Efficient marketing.

Ten years ago, cell and module production plants could remain viable by producing enough solar modules to generate just a few MW of power each year. Today's market leaders have plants with capacity above 1 GW, several hundred times than a decade ago. Capacity increases, combined with technological innovation and manufacturing optimisation, have radically reduced the cost per unit. The decrease is approximately 22% each time the production output is doubled (see Figures 13 and 22).

d. Increased performance ratio of PV systems

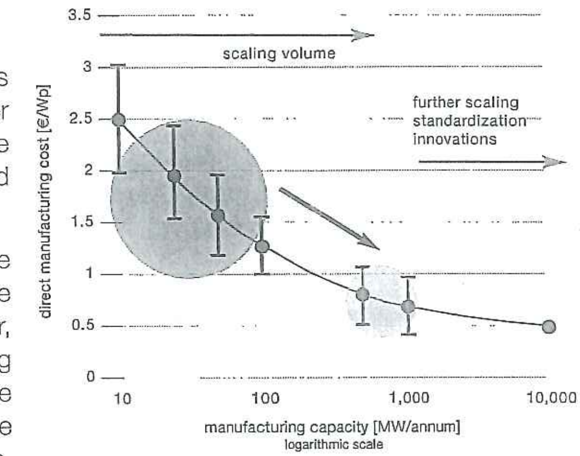
The cost per kWh is linked to PV system quality and reflected in its performance ratio (the amount of electricity generated by the module compared to the electricity measured on the AC side of the meter). The lower the losses between the modules and the point at which the system feeds into the grid, the higher the performance ratio. Typically, system performance ratios are between 80 and 85%. If losses can be reduced further, the cost per kWh can be lowered. Monitoring of systems enables manufacturers and installers to quickly detect faults and unexpected system behaviour (for example, due to unexpected shadows). This helps to maintain high performance ratios of PV systems.

e. Extended life of PV systems

Extending the lifetime of a PV system increases overall electrical output and improves the cost per kWh. Most producers give module performance warranties for 25 years, and this is now considered the minimum lifetime for a PV module.

The component that affects product lifetime the most is the encapsulating material. Intense research is being carried out in this field. However, the industry is cautious about introducing substitute materials because they need to be tested over the long-term. Today, PV modules are being produced with lifetimes of at least 25 years. The target is to reach lifetimes of 40 years by 2020 (see Table 10).

FIGURE 22
COST POTENTIAL FOR THIN FILM TECHNOLOGIES BASED ON PRODUCTION VOLUME AND MODULE EFFICIENCY
€/Wp



source: EU PV Technology Platform.

"When widely accepted by the industry standards, they contribute to reduce costs in design, production and deployment."

TABLE 10
PV TECHNOLOGY – 10-YEAR OBJECTIVES

Solar Europe Industry Initiative: PV technology roadmap for commercial technologies		2007	2010	2015	2020
Turnkey price large systems (€/Wp)*		5	2.5-3.5	2	1.5
PV electricity generation cost in Southern EU (€/kWh)**		0.30-0.60	0.14-0.20	0.10-0.17	0.07-0.12
Typical PV module efficiency range (%)	Crystalline silicon	13-18%	15-19%	16-21%	18-23%
	Thin Films	5-11%	6-12%	8-14%	10-16%
	Concentrators	20%	20-25%	25-30%	30-35%
Inverter lifetime (years)		10	15	20	>25
Module lifetime (years)		20-25	25-30	30-35	35-40
Energy payback time (years)		2-3	1-2	1	0.5
Cost of PV + small-scale storage (€/kWh) in Southern EU (grid-connected)***		-	0.35	0.22	<0.15

note: Numbers and ranges are indicative because of the spread in technologies, system types and policy frameworks.
* The price of the system does not only depend on the technology improvement but also on the maturity of the market (which implies industry infrastructure as well as administrative costs).
** LCOE varies with financing cost and location. Southern EU locations considered here range from 1,500 (e.g. Toulouse) to 2,000 kWh/m² per year (e.g. Siracusa).
*** Estimated figures based on EUROBAT roadmaps.

source: Solar Europe Industry Initiative Implementation Plan 2010-2012, Strategic Research Agenda.

f. Development of standards and specifications

The development of standards and consistent technical specifications helps manufacturers to work towards common goals. When widely accepted by the industry standards, they contribute to reduce costs in design, production and deployment. Standards also foster fair and transparent competition as all actors in the market must play by the same rules.

The industry targets for PV technology development in the period 2010 to 2020 are summarised in Table 10 and Figure 20.

"Next generation Photovoltaic present the greatest potential in cost reduction."

g. Next generation technologies

Next generation photovoltaics present the greatest potential in cost reduction. The main research activities in this field concentrate on increasing stability over the time and increasing the solar cell area. The industry targets for PV technology development of next generation technologies in the period 2010 to 2020 are summarised in Table 11 and Figure 20.

TABLE 11
MAJOR 10-YEAR OBJECTIVES AND MILESTONES FOR EMERGING AND NOVEL TECHNOLOGIES

Solar Europe Industry Initiative: PV technology roadmap for next generation technologies		2010	2015	2020
Commercial module cost for emerging technologies* (€/Wp)		N.A.	N.A	0,5-0,8
Typical PV module efficiency range (%)	Emerging technologies*	<7-12% Lab-scale***	10-15% Lab-scale***	>10% Commercial*****
		<5% Pre-Commercial****	<10% Pre-Commercial****	
	Novel technologies**	N.A	N.A.	>25%
Performance stability (years)		<5	5-15	>15

note: Numbers and ranges are indicative because of the spread in technologies, system types and policy frameworks.
* Emerging technologies include organic photovoltaics, dye-sentisised solar cells and advanced inorganic Thin Film technologies.
** Novel technologies include quantum technologies and technologies using nanoparticles.
*** Lab-scale: Cell Area below 10cm^2.
**** Pre-commercial: Sub-module area (combination of ~10 cells) below 0.1m^2 for consumer application.
***** Commercial: real scale module size >0.5m^2.

source: Solar Europe Industry Initiative Implementation Plan 2010-2012, Strategic Research Agenda.

3.3. PV in electricity networks and energy markets

With the development of on-grid systems, the integration of PV in electricity networks and energy markets has become a major challenge. This integration brings both benefits and issues for the PV sector.

a. High penetration of PV in the grids

In a typical electricity grid, electricity flows from the generation plants to the consumption devices via a distribution network. Electricity can also be transported between different areas to meet demand.

With small amounts of PV connected to the grid, most of the electricity produced is consumed at the site or in the immediate neighbourhood. As more PV electricity is added to the system, the transport network will also be used.

A recent study[14] has evaluated how much PV can be integrated into distribution networks without changing the network topology. The study found that Germany, which by end 2010 had more than 16,000 MW of PV electricity integrated into its network, is still a long way from exceeding grid limitations. Of course, local bottlenecks exist and the number will rise with the increasing penetration but this is not the general case. The study recommends that PV could account for up to 20% of supply without affecting the grid, under some technical developments.

Managing variability

Electricity network managers must ensure that the voltage and frequency of the electricity in the grid stays within predefined boundaries. To achieve this, managers must be able to forecast expected production and consumption each day to enable them to balance variations. PV electricity is, by nature, variable as it depends on Sun irradiation. For electricity network managers, predicting the available solar irradiation is generally quite accurate and easier than predicting wind patterns.

In large regions, the output from PV panels can be predicted easily and the network manager can plan how to best balance power supply. Local variability is smoothed out on the regional scale.

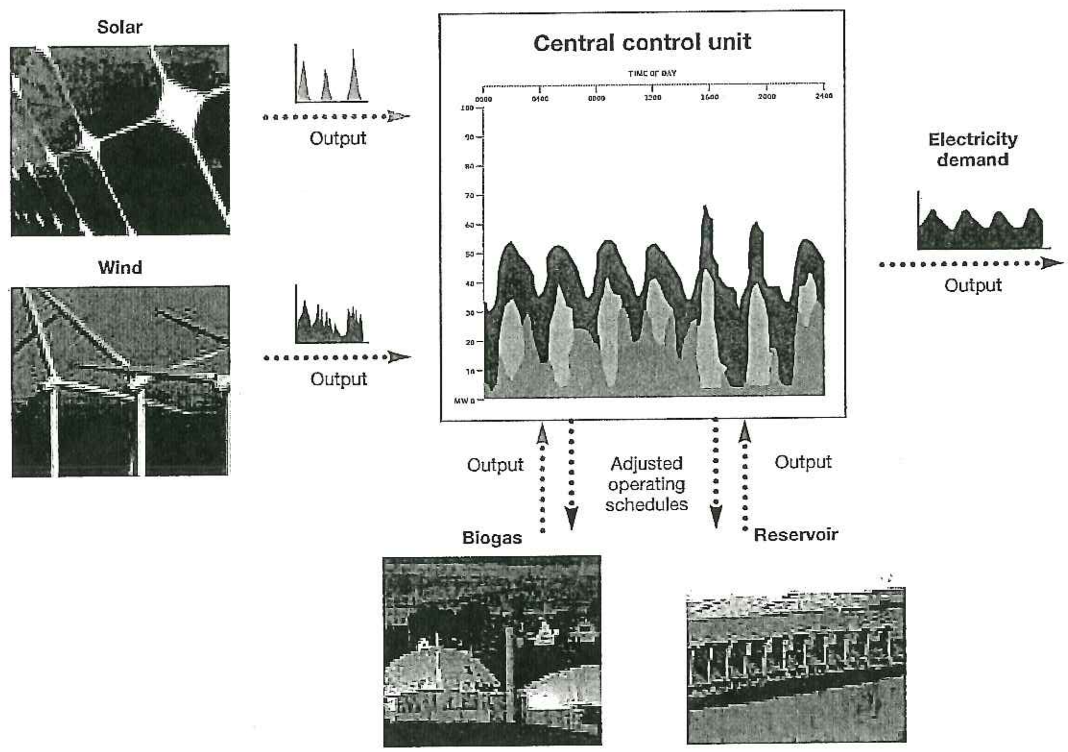
On an even larger scale, for example across a country, integrating large amounts of PV electricity into the grid requires network managers to dispatch balancing power in time to meet demand. Recent studies confirm that including a combination of different renewable energy sources on a large scale (such as across the European Union) can compensate for intermittent input from solar and wind sources. This enables managers to provide both peak load generation and also medium and base load. Network managers must also be able to dispatch part of the electricity load throughout the day (called Demand Side Management) to cope with the extra electricity coming from variable renewable sources.

"the integration of PV in electricity networks and energy markets has become a major challenge."

Virtual power plants (VPP)

Millions of small electricity generation devices, such as PV panels, cannot be managed in the same way as a handful of large power plants. The virtual power plant concept groups together large numbers of small- and medium-sized plants in the grid management system. This enables network operators to easily manage the electricity coming into the grid[15].

FIGURE 23
PRINCIPLE OF A 100% RENEWABLE POWER SUPPLY SYSTEM



source: www.solarserver.de/solarmagazin/anlagejanuar2008_e.html

b. From centralised to decentralised energy generation

In most developed countries electricity generation has been mainly centralised. However, many countries are now moving toward largely decentralised electricity generation. With wind turbines, small and medium biomass plants and solar power plants, electricity can be produced in a large number of places anywhere on the network.

The decentralised model means that electricity grid operators (DSO,* TSO**) must re-think how they guarantee the quality of the electricity delivery. This section discusses the main areas that require improvement and development.

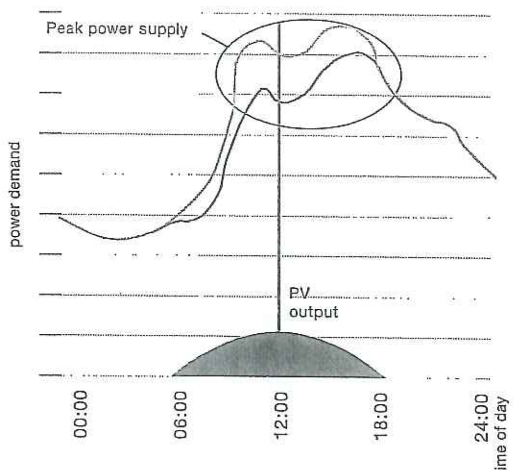
Peak load shaving

The daily electricity consumption curve has one peak at midday (in sunny countries) and sometimes (mainly in northern countries) a second peak in the evening. The pattern depends on climate conditions but the trend is clear. Figures 24 and 25 show how PV can play a key role effect on the midday peak. Known as peak shaving, the technique reduces the high power demand on the network at midday. Using storage systems, it is also possible to move some of the electricity produced during the day so the evening peak can also be shaved.

From smart grids to e-mobility

New renewable energy sources, decentralisation, and new ways of consuming electricity which modify load patterns require us to re-think grid management. The use of heat-pumps for heating (and cooling) and the future needs of electric vehicles (EVs) and petrol-hybrid electric vehicles (PHEVs) will require operators to improve their grids.

FIGURE 24
PEAK SHAVING NORTHERN EUROPE

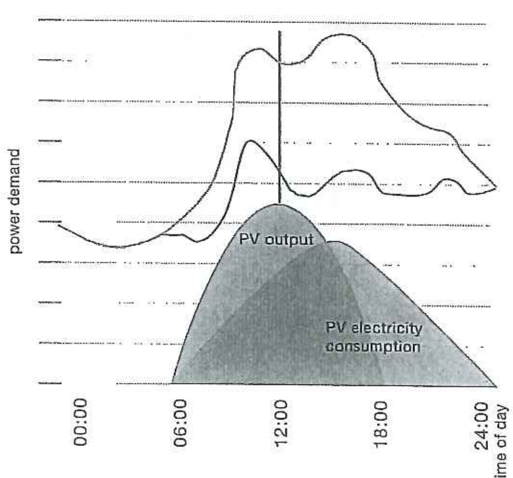


— ELECTRICITY DEMAND
— ELECTRICITY TO BE SUPPLIED BY OTHER SOURCES THAN PV

source: IEA-PVPS, Task 10.

"Many countries are now moving toward largely decentralised electricity generation."

FIGURE 25
PEAK SHAVING NORTHERN EUROPE WITH STORAGE



— ELECTRICITY DEMAND
— ELECTRICITY TO BE SUPPLIED BY OTHER SOURCES THAN PV

source: IEA-PVPS, Task 10.

* Distribution System Operator: the operator of the low and medium voltage electricity grid.
** Transport System Operator: the operator of the medium and high voltage electricity grid.

Super grid

The intermittent nature of renewable energy sources can be smoothed and balanced over large regions. This requires the enhancement of interconnections between countries and global management of the grid. In this way, wind electricity from windy countries can be mixed and balanced with solar electricity from sunny countries.

Smart grids

"The enhancement of interconnections can smooth the intermittent nature of renewable energy sources."

Smart grids are electricity grids that are more resilient and better able to cope with large shares of decentralised and intermittent energy sources. A better understanding of the demand and supply of electricity, coupled with the ability to intervene at the consumer level, enables supply to be balanced across a smart grid.

Decentralised storage

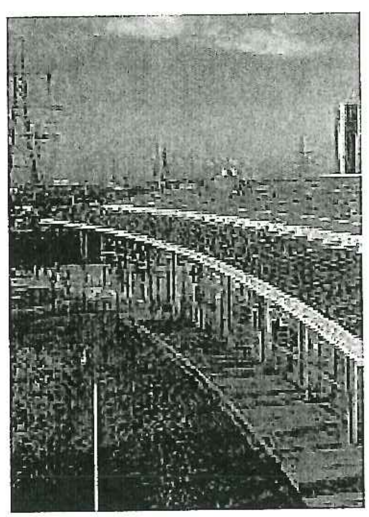
Decentralisation of electricity production also requires the decentralisation of energy storage. Today the major storage systems are hydro-pump facilities. In the future, small batteries and innovative concepts such as fly-wheels or hydrogen fuel-cells will be used as decentralised storage systems.

As electric-based transport develops, the many small batteries in electric vehicles can act as decentralised storage facilities while they charge overnight. The concept is known as vehicle to grid (V2G) and requires intelligent charge and discharge management.

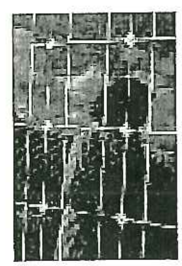
Demand-side management (DSM)

Load shaving is already used by network managers to reduce demand from large electricity consumers. Instead of looking for new production capacity, which is only used during peak periods, the concept of demand-side management (DSM) applies load shaving to almost every electricity consumer.

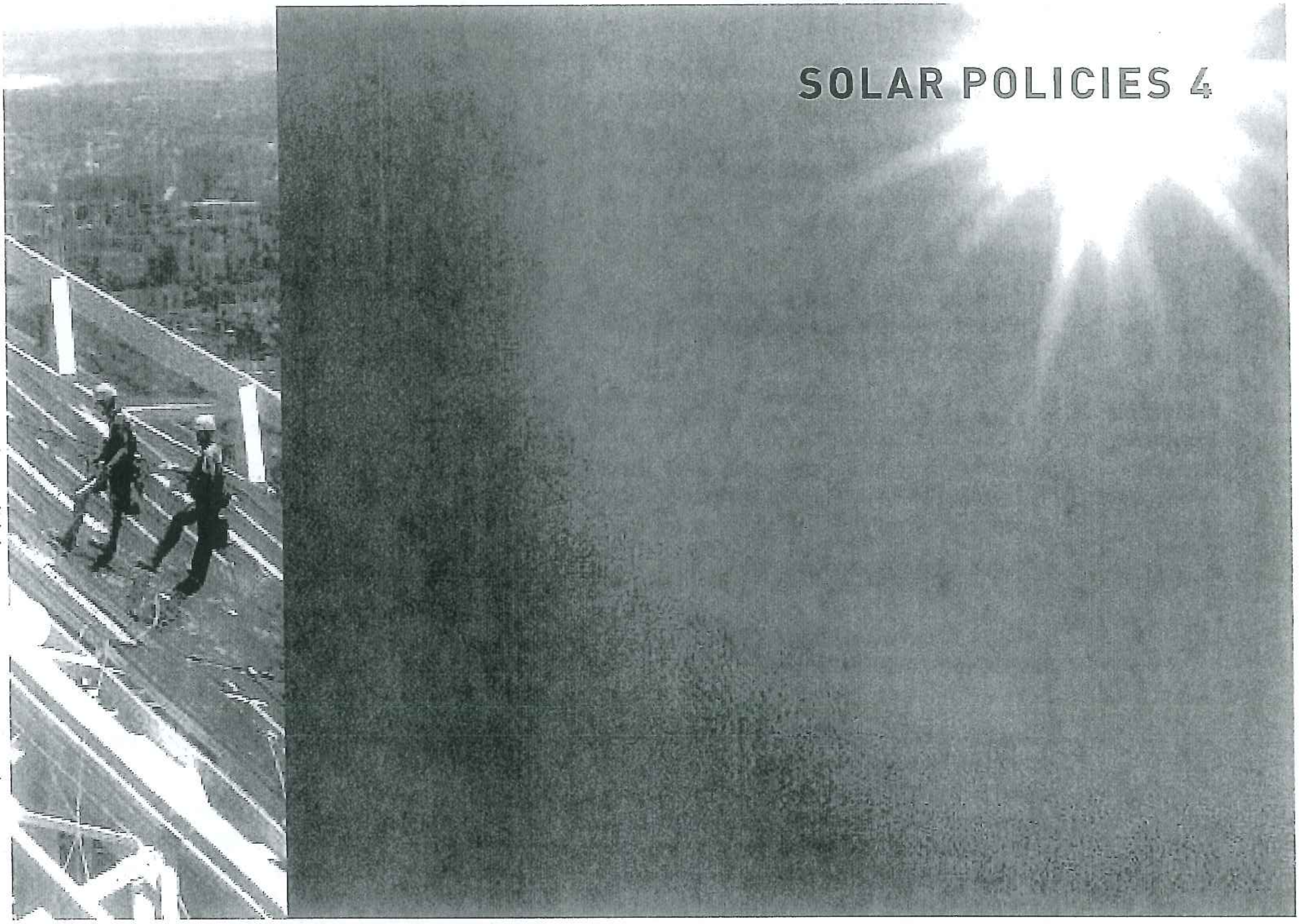
The time that many domestic electrical appliances are used could be delayed (for example, heat-pumps for washing machines, delaying EV recharge). This would be hardly noticeable to consumers. However, the concept could be used to help balance intermittent sources and better use energy when it is available.



PV system integrated on a roof.



PV module, Morocco.


SOLAR POLICIES 4

4. SOLAR POLICIES

4.1. Policy drivers for the development of solar PV

Clear meaures are essential to create a successful renewable energy policy which provides long-term stability and security of supply[16]. The four main elements of a successful renewable energy support scheme are:

1. *A clear, guaranteed pricing system to lower the risks for investors and suppliers and to lower costs for the industry*
2. *Clear, simple administrative and planning permission procedures*
3. *Priority access to the grid with clear identification of who is responsible for the connection, and what the incentives are*
4. *Public acceptance and support.*

"FiT have been introduced around the world and helped to develop new markets for PV."

a. Public awareness Feed-in Tariffs: Key driver of solar success

It is surprising that Germany, not a particularly sunny country, has developed a dynamic solar electricity market and a flourishing PV industry. The reason is that the government has introduced a Feed-in Tariff (FiT) scheme that guarantees a price for all renewable electricity that is fed into the grid. Wind-powered electricity in Germany is currently up to 40% cheaper than in the United Kingdom[17] because of the FiT.

FiT have been introduced around the world and helped to develop new markets for PV. They have been supported in key reports by the European Commission (2005 and 2010 industry surveys[18]) and the *Stern Review on the Economics of Climate Change.* Globally, more than 40 countries have adopted some type of FiT system, with most adjusting the system to meet their specific needs.

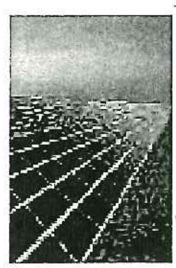
Extending FiT mechanisms is a cornerstone to promote the production of solar electricity in Europe. The concept requires that producers of solar electricity:

- Have the right to feed solar electricity into the public grid
- Receive a premium tariff per generated kWh that reflects the benefits of solar electricity compared to electricity generated from fossil fuels or nuclear power
- Receive the premium tariff over a fixed period of time.

All three points are relatively simple, but significant efforts were required to be achieved.

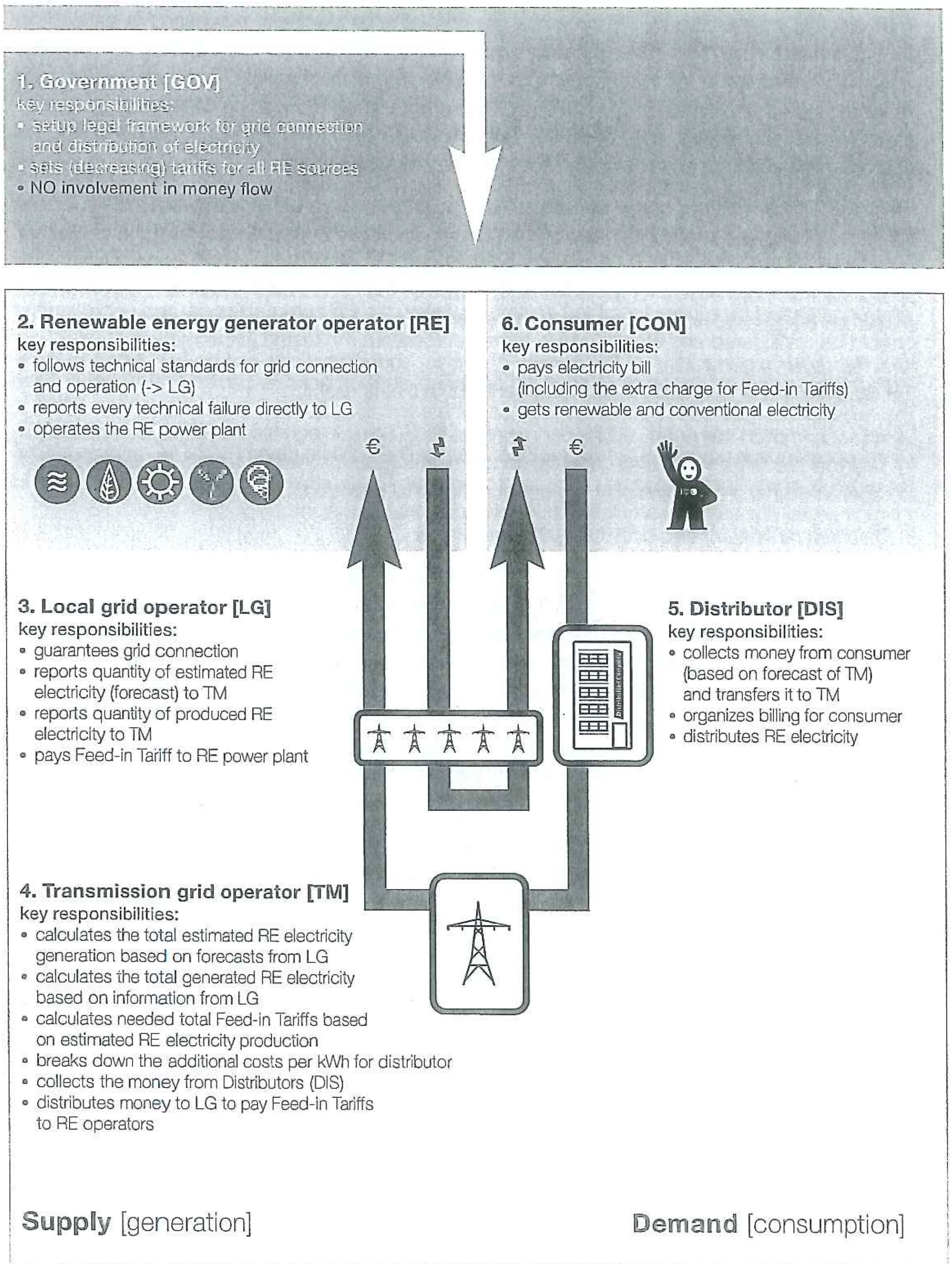
The key attributes to a successful FiT scheme are:

- *They are a temporary measure.* FiT schemes are only required for the pre-competitive period until solar PV reaches grid parity.
- *Costs are paid by utility companies and distributed to all consumers.* This ensures the non dependence of the government budgets.
- *FiTs drive cost reductions.* The tariff should be adapted each year, for the newly installed PV systems.
- *FiT encourage high-quality systems.* Tariffs reward people who generate solar electricity, but not those who just install a system. It then makes sense for owners to keep their output high over the lifetime of the system.
- *FiT encourage PV financing.* Guaranteeing income over the life of the system enables people to get loans to install PV. It also makes this kind of loan structure more common and simpler for banks and PV system owners.



Large Thin Film power plant.

FIGURE 26
FIT – HOW DOES IT WORK IN PRACTICE?
AN EXAMPLE OF THE MECHANISM OF A FEED-IN TARIFF
FOR SUSTAINED COMPETITIVE GROWTH



source: Greenpeace International.

"It is necessary to foresee changes in market conditions and adapt FiT to ensure a sustainable growth path."

Key Recommendations for sustainable support for PV

EPIA has developed the following key recommendations for policy-makers so they can implement adequate support schemes for PV:

1. Use Feed-in Tariffs or similar mechanisms

Feed-in Tariff laws introduce the obligation for utilities to conclude purchase agreements for the solar electricity generated by PV systems. The cost of solar electricity purchased is passed on through the electricity bill and therefore does not negatively affect government finances. In markets, where FiTs were introduced as reliable and predictable market mechanisms, they have proven their ability to develop a sustainable PV industry that has progressively reduced costs towards grid parity. In order to be sustainable, it is critical that FiTs are guaranteed for a significant period of time (at least 20 years), without any possibility of retroactively reducing them.

Feed-in Premium (FiP) is a new mechanism that may prove to be a viable alternative to FiTs. Under the FiP, utilities pay a premium on top of the price of electricity while the invoice of the consumer is reduced by the amount of PV electricity produced. If PV electricity exceeds consumption, the difference should be eligible for a feed-in tariff. However, the FiP concept is new and unproven but should be considered and worked out in more detail before it is tested in the market.

With the growing penetration of PV in many countries, support policies can be fine-tuned to drive the development of a specific market segment where this is useful.

Direct consumption premiums, additional incentives for Building Integrated PV (BIPV), compensation for regional irradiation variations, orientation premiums (East or West-oriented PV systems and storage premiums are all examples of possible additional provisions.

2. Ensuring transparent electricity costs for consumers

As the cost of renewable energy sources such as PV is very transparent to the consumer through the FiT component on the electricity bill, it will be important going forward to create the same transparency for the cost of generating electricity from other, conventional, sources. These typically benefit from significant government support schemes that are not always reflected in the electricity price but are financed through other public means; in particular taxes paid by those same consumers but not accounted for on the electricity bill. On average, estimates suggest that conventional sources of electricity generation benefit from seven times as much support as renewable energy sources. In addition to this direct financial support comes the indirect support of non-renewable energy through the lack of including transparent carbon costs.

The increased mix of energy from renewable sources such as PV has created a greater awareness among consumers about the need to increase the efficiency with which they consume electricity. So while the FiT has a visible impact on the electricity bill, it is at least partially compensated by the decrease of electricity demand. In addition, marginal cost of electricity produced from PV systems after the expiration of the FiT period is close to zero which will benefit electricity prices in the long term.

Most importantly and in view of continued reduction of FiTs over time, the PV industry is committed to significantly reducing the cost of PV systems to make it an affordable, mainstream source of power.

3. Encourage the development of a sustainable market by assessing profitability on a regular basis and adapting support levels accordingly

Sustainable market growth allows industry to develop and creates added value for the society and the economy as a whole. A critical aspect of sustainable development is ensuring adequate levels of profitability that ensure the availability of capital for investments while avoiding speculative markets. Overall, investments in PV projects need to be at par with other investments with equivalent risk levels. The figure to the right illustrates market developments under different support strategies. The green line represents a sustainable market growth. The red line shows a rapid and uncontrolled market peak, followed by a collapse due to sudden policy adjustment, while the blue line illustrates a stagnating market due to an incentive deemed insufficient.

Assessing the profitability through IRR calculations. All available support scheme components (including FiT, tax rebates and investment subsidies) must be taken into account when calculating the Internal Rate of Return (IRR) of a PV investment. Its sustainability must be assessed considering all local factors that impact the relative profitability of a PV investment. The table 1 presents an estimate of average sustainable IRR levels in a standard European country. Those percentages need to be adapted depending on local market conditions.

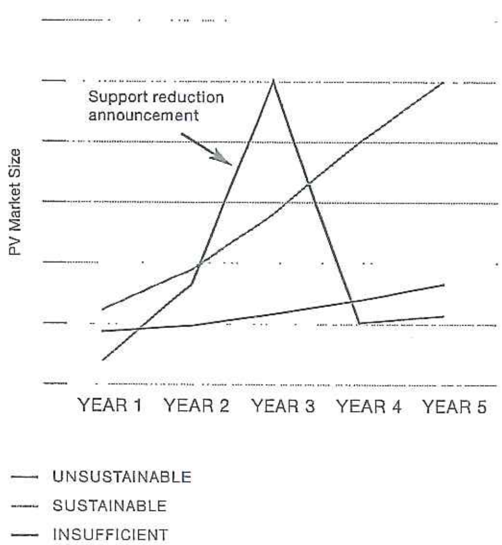
4. Gradual market development with the corridor concept

An uncontrolled market evolution tends to create "stop-and-go" policies that risk undermining stakeholders' confidence in and investor appetite for PV. In that respect, there is a need for a flexible market mechanism that is able to take into account more rapid cost digressions in the market and to adapt support schemes in order to ensure a sustainable growth path. The market corridor – as introduced in Germany for example - regulates the FiT based on market development over the previous period, thus allowing FiTs to be adapted so as to maintain growth within predefined boundaries. The FiT level is decreased on a regular basis in relation to the cumulated market level over a period passing below or above a set of predefined thresholds (quarterly or semi-annual revisions). The review periods should typically be set at once a year to keep the administrative burden manageable for governments and to remain compatible with the visibility needed for investment cycles.

5. Developing a national roadmap to PV competitiveness

With the ongoing decrease in installed PV system costs and the increase in conventional electricity prices, the use of financial incentives will progressively be phased out, as competitiveness is reached. A realistic roadmap to grid parity should be defined for every country along with concepts for market mechanisms that treat all electricity sources equally.

FIGURE 27
PV MARKET DEVELOPMENT UNDER DIFFERENT SUPPORT STRATEGIES



source: EPIA.

TABLE 12
ILLUSTRATIVE INTERNAL RATE OF RETURN LEVELS

	Insufficient Support	Sustainable Support	Unsustainable Support
Private investor	< 6%	< 6-8%	> 8%
Business investor	< 8%	< 8-12%	> 12%

b. Other drivers of a successful PV market development

Streamlining administration procedures

To help keep project costs down and avoid unnecessarily high levels of FiT, EPIA has made three recommendations for the management of FiT schemes:

1. *Assess the administrative process.* Policymakers should aim for a process that is transparent, linear in approvals, simple, cost-effective and proportional in effort for the owner. Long administrative delays or requirements that applicants contact multiple agencies or government bodies increases the lead time and cost of new projects. All authorisations, certifications and licensing applications should be assessed and delivered through a one stop-shop. In addition a reliable monitoring system must be ensured.
2. *Reduce administrative lead times to a reasonable period.* Short lead times must be a priority, especially for small-scale systems. Any delay in the authorisation process means less profitability for the investor. This reduces return and makes the project less attractive. Support schemes should provide automatic approval for small systems if no action is taken by the body responsible within a reasonable time limit.
3. *Simplify and adjust support schemes levels.* Once the administrative process has been simplified, the FiT should be adapted (lowered) when it has created cost reductions for suppliers. If this is not done, PV projects become too profitable, creating an unsustainable market that is likely to crash.

"Streamlining administration procedures help keep project costs down and avoid unnecessarily high levels of FiT."

"Grid connection agreements are crucial because they give confidence to the investor by guaranteeing that the electricity produced will be sold and transported."

Guaranteeing efficient grid connection

Grid connection agreements are crucial because they give confidence to the investor by guaranteeing that the electricity produced will be sold and transported. However, grid connection is often the most severe roadblock on a PV project. It can delay the project and dramatically increase its overall cost. EPIA recommends:

1. *Assess the grid connection process.* The assessment should focus on transparency, providing comprehensive information, an appropriate notification requirement, guaranteed lead times and cost-sharing between the PV operator and the distribution system operator DSO.
2. *Reduce grid-connection lead time to a few weeks.* Delays in the authorisation process must be avoided to guarantee short lead times and investor returns. Electricians should be accredited to connect small-scale systems to the grid with only a notification to the distribution system operator DSO.
3. *Ensure priority access to the grid.* Once the connection permit has been granted, the transport and distribution of the electricity produced by PV systems should be guaranteed for the lifetime of the installation.
4. *Deliver grid connection permits to reliable project developers.* Policy announcements can be followed by a flood of grid connection requests, in such a way that virtually all existing capacity could be exhausted. To avoid such a situation and counteract speculation, permits must only be issued to reliable investors. Validity of permits must be limited in time, and large project developers can be asked for bank guarantees to ensure they live up to their commitment.

6. *Ensure the financing of network operators.* The benefits that PV brings to electricity networks, especially at the distribution level, come at a cost, meaning that necessary investments must accompany the development of PV and its smooth integration on electricity networks. Ensuring funding for DSOs or TSOs can be necessary to secure maintenance and upgrade of the electricity grid.