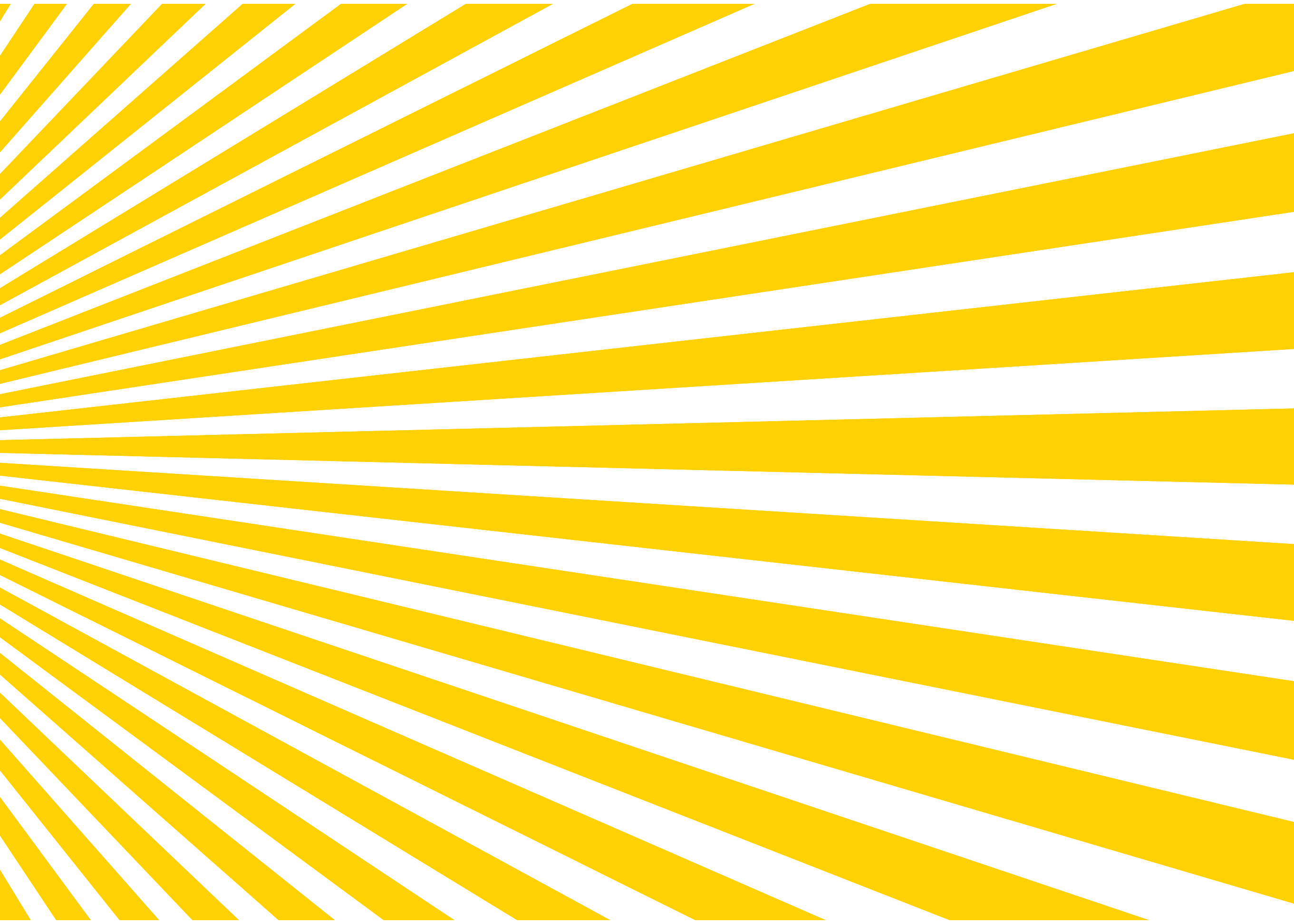
THINK ACT

BEYOND MAINSTREAM



SOLAR PV

could be similar to the shale gas disruption for the utilities industry

JUNE 2015

Roland Berger Strategy Consultants

THE BIG 3

1 <1%

The share of traditional utilities in the European installed solar PV capacity is less than 1% at the end 2014. The remaining 99% is owned by investors, project developers, households and commercial companies and they compete with utilities in electricity generation.

p. 14

2 12%

The share of solar PV electricity production in total European electricity production can reach 12% by 2030, quadrupling the share in 2013. Solar PV will start to have a large impact on the business model of utilities.

p. 16

3 17 cts/kWh

The electricity retail price, including taxes, grid fees and the EEG levy equals 29 cents/kWh in Germany, while the feed-in tariff for residential rooftop installations equals only 12.5 cents/kWh. Raising self-consumption with home automation tools and storage enables consumer to put the difference of 17 cents/kWh in their pockets, threatening the traditional utilities offer.

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New business models for utilities p. 18

Introduction: Solar PV could be a game changer for the utility industry

In just 30 years, solar PV has developed from a niche segment into a high growth market. Once mainly used in remote locations, it is now installed on all types of rooftops and land sites on all continents, almost regardless of irradiation. Solar PV is therefore moving into a position to become a game changer for the utility industry. We see this move as disruptive for the utilities industry as the shale gas revolution that dramatically impacted the whole energy landscape.

Solar PV enables energy consumers to produce power. Its energy is produced at the site of consumption; this decentralization reduces the need for transmission. Utility companies, whose business models are based on centralized power generation and one-way transmission, will have to prepare for the lower volumes and lower peak loads, for the reduced revenues and margins in turn. But solar PV not only presents challenges; it also creates new opportunities for energy delivery and for the services that will install, maintain and operate these new facilities. As it depends on the sun, the production profile of solar PV is intermittent depending on solar irradiation and clouds. Production is highest around noon and absent during the night. New solutions will have to be developed that can deliver consistent electricity to meet demand. Utilities, in redefining their business models to match this new state of affairs, can position themselves to play an important role in matching energy supply and demand in the decades to come.

This paper describes the challenges and opportunities for utilities posed by solar PV. The following section briefly discusses the historical development of solar PV. The third section highlights the drivers of solar PV, why consumers buy and install solar PV panels. The fourth section then considers the forecasts for the penetration of solar PV worldwide and for Europe in more detail. In the fifth and sixth sections, the impact on utilities, and the transmission and distribution companies respectively, will be discussed. The main findings and conclusions are presented in the final section.

Solar PV has developed from a niche market into a high-growth industry

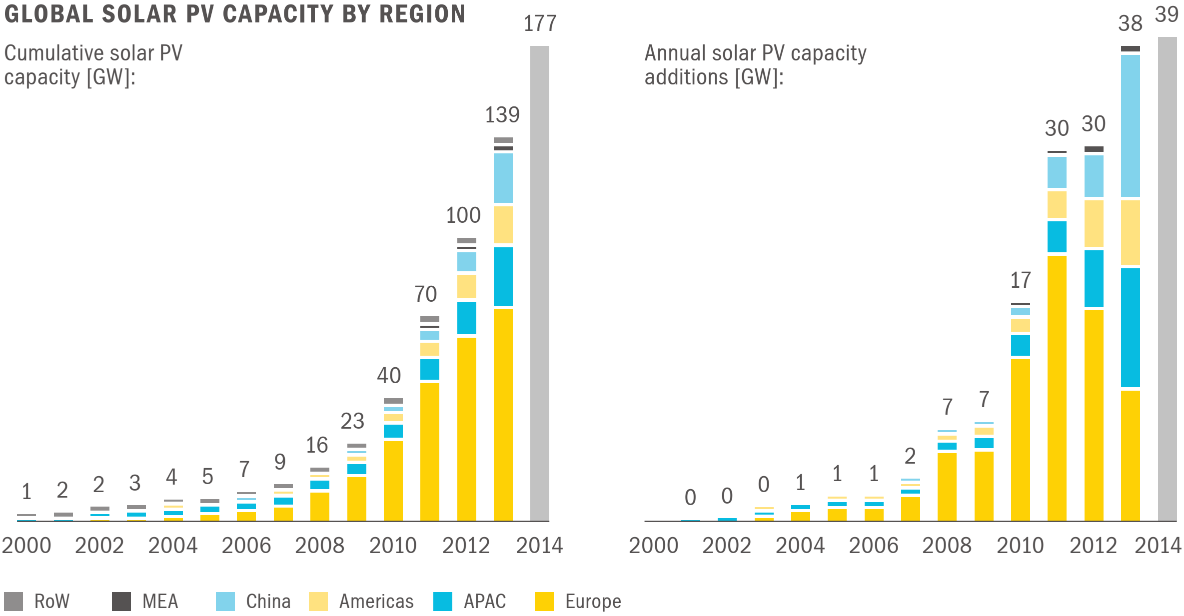
The photovoltaic effect was proven in 1839, but it was not until 1950 that the first solar cells were produced for satellites. In the late 1970s, solar PV was used to power remote and off-grid locations. In the early 1990s, governments in Germany, Japan and the US started the growth of the solar PV sector through special programs that targeted both deployment and the build-up of a domestic industry. For instance, Germany's "1,000 roofs" and "100,000 roofs" programs built its industry's capabilities in solar panel rooftop installation. Likewise, the Japanese government's New Sunshine Project created a solar photovoltaic industry and a domestic market for solar power.

Since these early initiatives, government policies for solar PV have matured, and many countries began to offer feed-in tariffs, net metering regulations, tax credits or other support schemes to encourage installation. Over time, though focus has shifted to reducing CO2 emissions, the aims driving the solar PV sector still include building a cleantech industry and reducing foreign dependence for fuel.

As shown in figure A, the solar PV industry has grown exponentially. In 2014, worldwide nominal capacity installed totaled 177 GW; each year, this capacity grows by about 40 GW.

A

GLOBAL SOLAR PV CAPACITY BY REGION

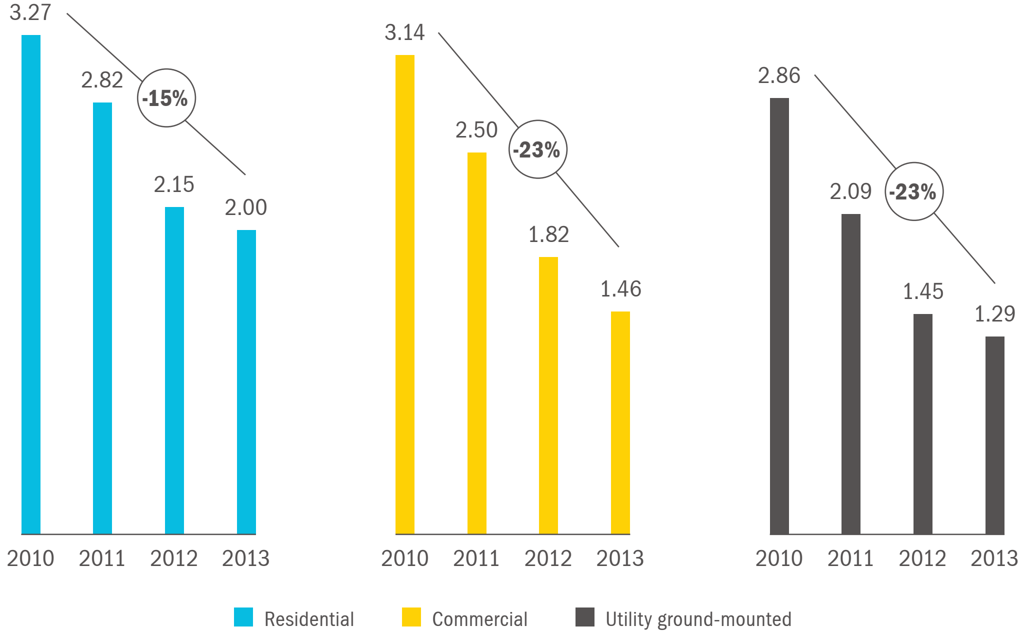


Source: EPIA, Roland Berger

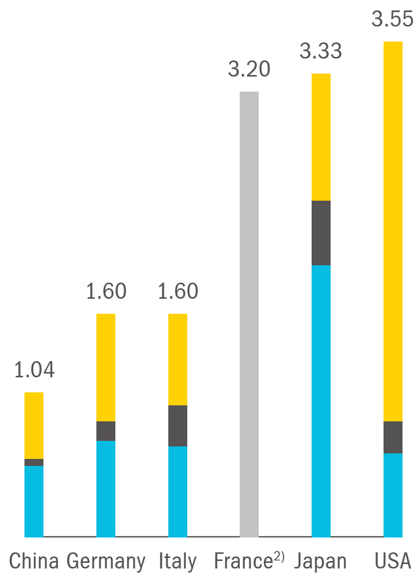
B

PRICING

SYSTEM PRICE EVOLUTION - EUROPE[1)] [EUR/WATT$_P$]



RESIDENTIAL SYSTEM PRICE COMPARISON [2013; EUR/WATT$_P$]



As of 2013, system prices were heterogeneous across regions, with residential prices in the US and Japan being about twice as high as in Germany and three times higher than in China.

Prices of modules are similar across Europe, the US and China, but are exceptionally high in Japan, where 90% of modules are built domestically in a two-tier wholesale system in which suppliers show high bargaining power. System prices are also higher in France than in other EU countries, as the French state has favored the development of locally-produced higher value-added building-integrated modules (ISB and IAB).

The key price difference between US and German systems are not hardware related but depend on "soft costs". In Germany, higher average system sizes lead to economies of scale, and scale and experience effects account for lower installation labor and overhead costs. On the contrary, the US market is more fragmented and has more complex interconnection and permitting procedures leading to higher BoS costs.

1) Weighed average for Belgium, France, Germany, Austria, Spain, Italy and Sweden
2) France: prices for ISB (Simplified Building Integration) ; Component prices unavailable
Source: IEA PVPS, Roland Berger

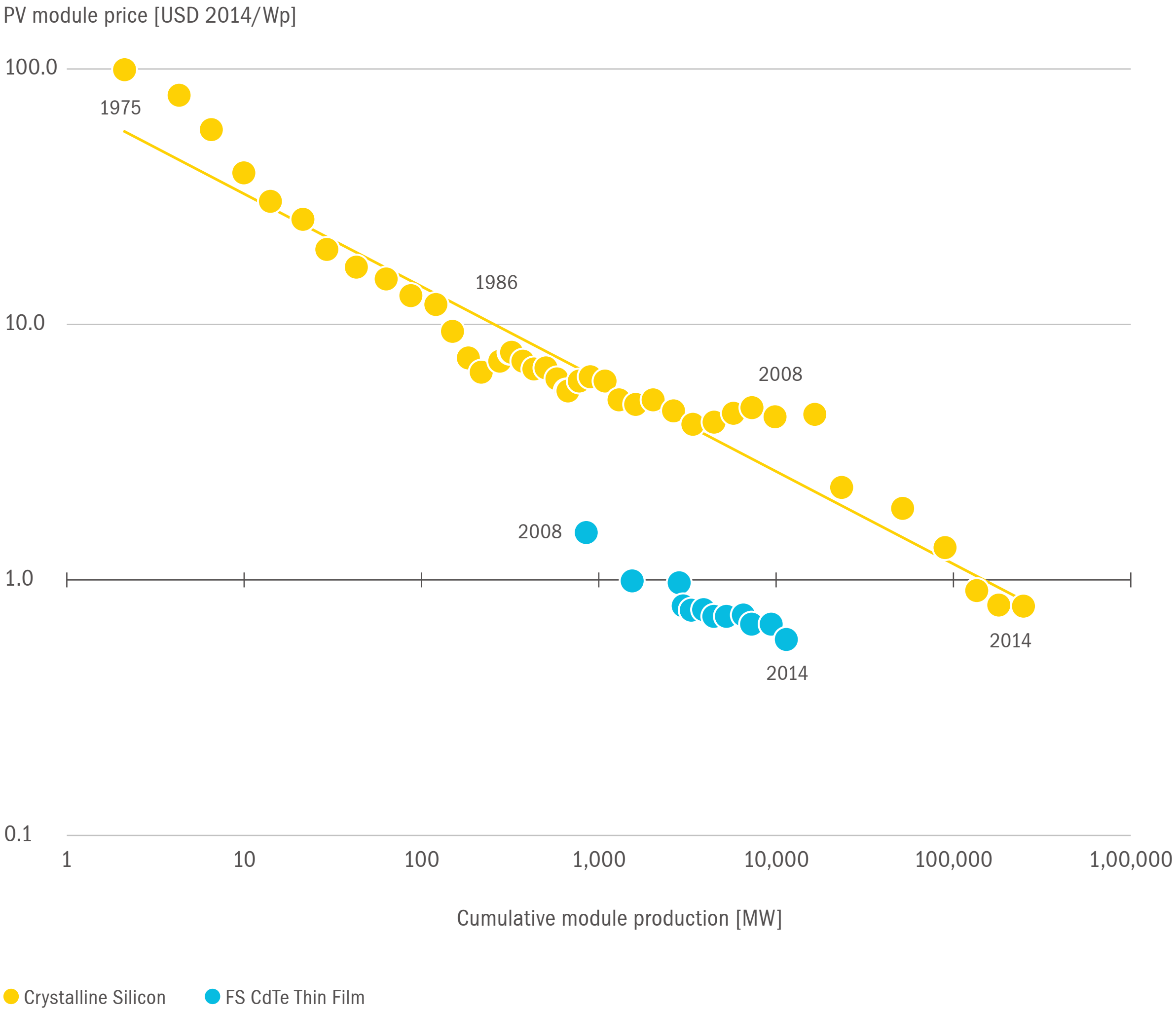
Most installed capacity is located in Europe, but with solar PV's expansion China and Asia in general are seeing the highest growth.

As the number of installed solar PV panels has grown, the price of solar panels has come down. This effect, of course, was the intention behind government initiatives to provide financial support to buyers of solar PV. Prices for panel modules have dropped from around USD 100 per watt peak (Wp) in 1975 to below USD 0.60/Wp in 2014. C

Total system prices have also fallen, dropping 15-23% per annum between 2010 and 2013. Depending on the application and region, a solar PV system at the end of 2013 cost between USD 1.29/Wp for a utility ground-mounted system and USD 2.00/Wp for a residential rooftop system in Europe. The balance of system (BOS), including installation, is now at ca. 50% of the system's total costs. B

C

SOLAR PV EXPERIENCE CURVE [MW, USD/WATTP]



Source: Bloomberg New Energy Finance, PV news, European Commission-DG Joint Research Centre, Roland Berger

Decreasing costs and new technological and commercial developments make solar PV a viable source of electricity

Solar PV systems are installed on roofs of buildings and on land at a utility-scale. Owners can be either the owners of the roofs themselves, or investors who rent the roofs for the installation. Utility-scale installations are built by a diverse range of players, including investors, project developers and utilities. The purchasing decision is different for each type of player, since the value of a solar PV system varies by its use, the buyer's ability to sell electricity at attractive prices, the applicable regulations, and, especially for households, the ease of purchase.

This section describes the drivers for solar PV in more detail: the cost evolution of solar PV (1), evolutions in the regulatory framework (2), new technological developments that can raise the value of solar PV (3), and new commercial developments that make the decision to buy a solar PV system easier (4).

1. Cost evolution

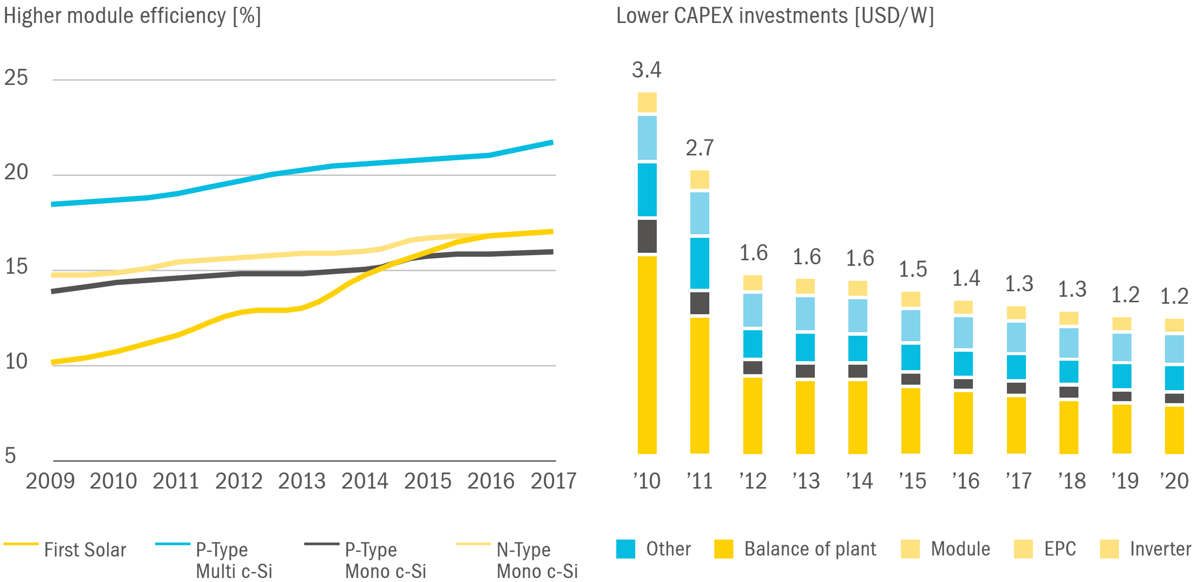
The two main reasons to buy a solar PV system are: (1) that the electricity generated can be sold at a profit, or (2) that the electricity generated is cheaper than buying it from a utility company or obtaining it from an alternative source. In the purchasing decision, utilities will compare the levelized costs of electricity (LCOE[1)]) of solar PV with the wholesale electricity price. Households, on the other hand, will compare the LCOE with the residential electricity price, including grid and retail costs and taxes. Though residential systems may be more expensive than utility-scale system, the higher residential electricity price as reference still makes them attractive. An often overlooked item in this cost comparison, however, is the difference in the cost of capital for consumers versus investors. Whereas investors use a market-based weighted average cost of capital, consumers often compare a solar PV investment with the interest rate on their savings account. This further raises the attractiveness of an investment in solar PV by households. Commercial players in the SME segment have adopted a professional view in making their larger-scale investments in solar PV, while benefiting from retail prices and legal certainty of feed-in regulation in their business cases.

Since solar PV used to be more expensive than the wholesale or retail power price, governments have provided subsidies to bridge the difference and promote increased installation. Now, solar PV system prices have come down; in certain cases, subsidies are no longer even needed. Other areas of regulatory activities become more vital, such as net metering, feed-in priorities, take-or-pay obligations and the like. The continuing cost reductions are coming from higher module efficiency, cheaper parts production, as well as lower installation costs. The price of solar modules, for example, dropped 10-fold between 1995 and 2014. The BOS and inverter now make up 50% of the total costs of a residential solar system.

1) The LCOE (levelized cost of energy) is a metric for the cost of electricity produced by a generator. It is calculated by accounting for all of a system's expected lifetime costs (including construction, financing, fuel, maintenance, taxes, insurance and incentives), which are then divided by the system's lifetime expected power output (kWh).

D

DECLINING LCOE THROUGH TECHNOLOGICAL PROGRESSION



CONTINUOUS DECLINE IN LCOE
Global average LCOE of solar PV is estimated to have declined by around half between 2010 and 2014. **Rapid** advancements in technology leading to higher module efficiencies coupled with lower module / inverter costs and increasingly competitive structures in most markets pave the way for lower LCOEs going forward. **Deutsche Bank** predicted that 80% of solar systems gloablly will be at grid parity with conventional energy in 2 years. **Penetration** rates of solar electricity set to surge with such a clear trend of declining LCOE

Source: Bloomberg, Agora, IRENA, Deutsche Bank, Roland Berger

And the potential for further cost reductions is considerable; Deutsche Bank predicts a 40% reduction in total system costs by 2017[1]. D

The LCOE of solar PV has also come down, reaching USD 119-318/MWh for utility-scale systems and USD 135-539/MWh for residential application. LCOEs will decline furthers. The LCOE ranges are large due to the significant differences in irradiation, import levies on modules, BOS, and the differences in installation costs between countries and their chosen weighted cost of capital. These ranges, however, are expected to shrink, as shown in figure E.

3 As a result of the low system prices, grid parity has already been reached in many countries, including Germany, Spain and Italy in the residential applications, where the price of solar PV compares with the regular retail price, including transport costs and taxes. In Germany the retail price is 17 cents/kWh higher than the feed-in tariff (as proxy for the LCOE), making the purchase of a solar PV system a viable alternative. The recent tender for a utility-scale solar PV system in Abu Dhabi at a price of USD 59.80/MWh also reveals that grid parity has been reached at wholesale prices in certain other regions. The continued decline of LCOEs will increase the robustness of grid parity in the residential segment, as well as in utility-scale solar PV, which will be able to compete with wholesale prices in more countries around the world.

That said, further cost reductions are needed to foster large-scale uptake. The price of decentralized solar PV electricity injected into the grid greatly determines the profitability of the household system[1]. Most consumers do not use all the power they generate at home; in Germany, for example, the average is between

1) Deutsche Bank, *Crossing the Chasm*, February 2015.
2) Note that in some countries, all generated power has to be transmitted into the grid at a predefined price. It is then purchased at a similar cost.

20-30%. If feed-in tariffs are lower than the LCOE, the profitability of the system is reduced.

Taxes also help determine – or discourage – uptake. In some countries, like the Netherlands, solar PV consumption is tax-exempt. The retail electricity bill also often does not include large fixed elements, like a capacity fee for access to the grid, which would reduce the price differential between solar PV and retail electricity. If solar PV is taxed or fixed elements are introduced, lower LCOEs will be required to ensure solar PV's attractiveness.

2. Regulation

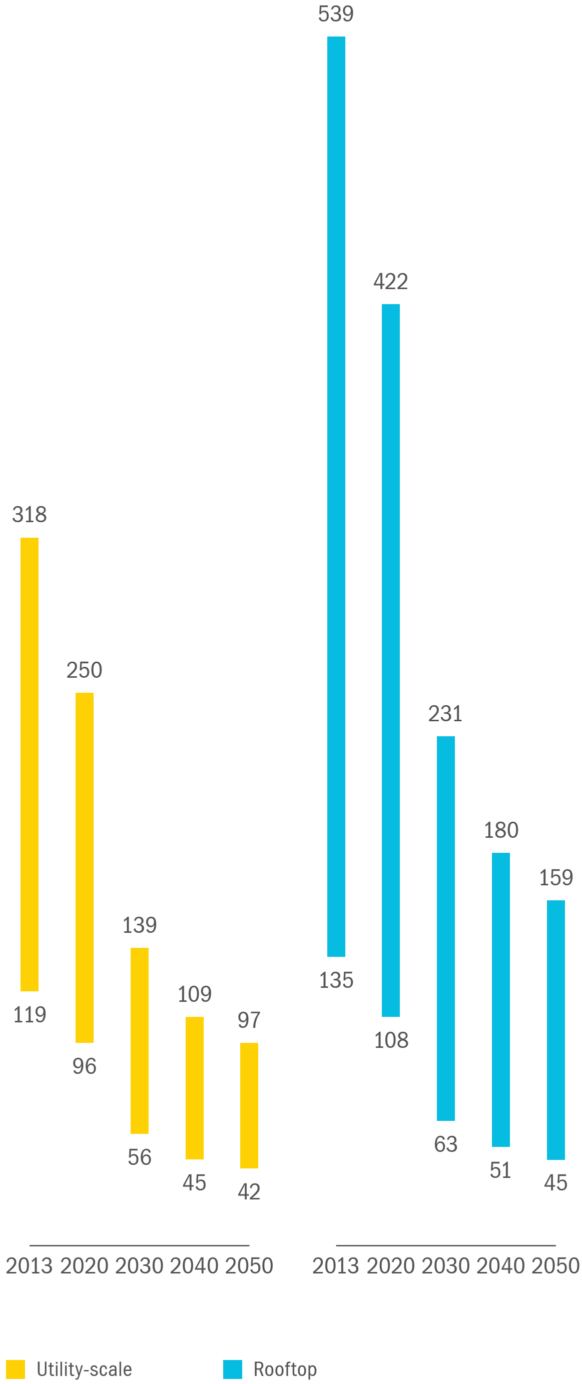
Before solar PV reached grid parity, many governments offered subsidies for solar power generation and devised special rules for grid access. Now, governments are gradually phasing out these subsidies and rules, as development has gone faster than expected, targeting a certain range of annual installations and adapting their support accordingly.

In Germany, for instance, the feed-in tariff is now being reduced every month for installations up to 10 MW. There is no support for installations above 10 MW. Since 2012, private consumption of electricity from a home's solar PV system does not receive any means of support, though households do not have to pay the EEG levy (renewable energy support scheme) on the electricity they use – which amounts to cents 6.17 cents/kWh for the average household (based on April 2015 figures). Larger utility-scale installations have to bid in an auction to receive a market premium on the solar PV electricity price. Germany has also announced that when total installed capacity reaches 52 GW, no more subsidies for solar PV will be given. Current capacity stands at 38 GW.

In France, the feed-in tariff is also being gradually reduced. The LCOE will eventually become lower than the regulated tariff, especially in the south. Setting its feed-in tariffs and auctions, the French government targets annual installations of 1,000 MW. In the UK, with its lower irradiation levels, consumers still receive a generation stipend for solar PV, but the level of this stipend is also being gradually lowered.

E

LEVELIZED COST OF ELECTRICITY OF SOLAR PV [USD/MWH]



Source: IEA, Roland Berger

Larger utility-scale installations need to bid for a Contract for Difference for installations larger than 5 MW.

Overall, the nature of the regulation of solar PV is expected to transition from promoting uptake to reducing negative externalities on the energy system. Given that consumers do not usually consume most of their own household's PV generated electricity, the feed-in of this excess energy and the grid connection itself will be regulated, especially in the residential and small commercial segments. Such regulation, however, is expected to temporarily discourage, rather than promote, solar PV uptake – though this effect will fade once wholesale price grid parity is reached. This regulation will likely take three forms.

First, new regulation will arise on the prices at which households can feed-in their excess power into the grid. These feed-in prices can be well below the wholesale prices given their non-dispatchable nature and the location of injection. However, when self-consumption levels reach 50%, and at current LCOEs of less than 50% of the retail price, solar PV will still be a profitable investment even if all excess electricity is wasted. Therefore, this type of regulation is not expected to drastically affect solar PV.

Second, new regulations will force consumers to pay for their access to grid capacity, rather than for their use of that capacity. Under current schemes, solar PV owners pay relatively little for their use of the grid capacity, whose price depends on total retail electricity consumption. However, grid costs depend more on fixed assets than on use, so households with no solar PV pay a disproportionate share of the total costs – an indirect incentive to switch to solar PV. Changing the cost allocation in this regard will delay solar PV uptake, but not indefinitely, since grid parity will just be reached later.

Third, taxes and levies on self-consumption of electricity will also arise. Unlike retail electricity, electricity from solar PV is currently tax-exempt in most countries. This tax scheme incentivizes energy efficiency and helps finance the still uncompetitive renewable electricity. Governments may well impose taxes on solar PV electricity in order to treat all household energy systems equally. The German government, in fact, has imposed 30% of the EEG levy on self-consumption of electricity from solar PV installations on commercial buildings. Such taxes and levies will slow solar PV uptake, but will have no impact once the LCOE has reached wholesale power grid parity.

3. New technological developments

Even though the LCOE of solar PV is already lower than the retail electricity price, solar PV is not yet attractive for all households. Most consumers only use 20-30% of their privately generated electricity, and often receive only a break-even fee for the electricity they feed-in the grid. Storage solutions, like batteries, demand-side management, and other smart home solutions would raise the self-consumption ratio.

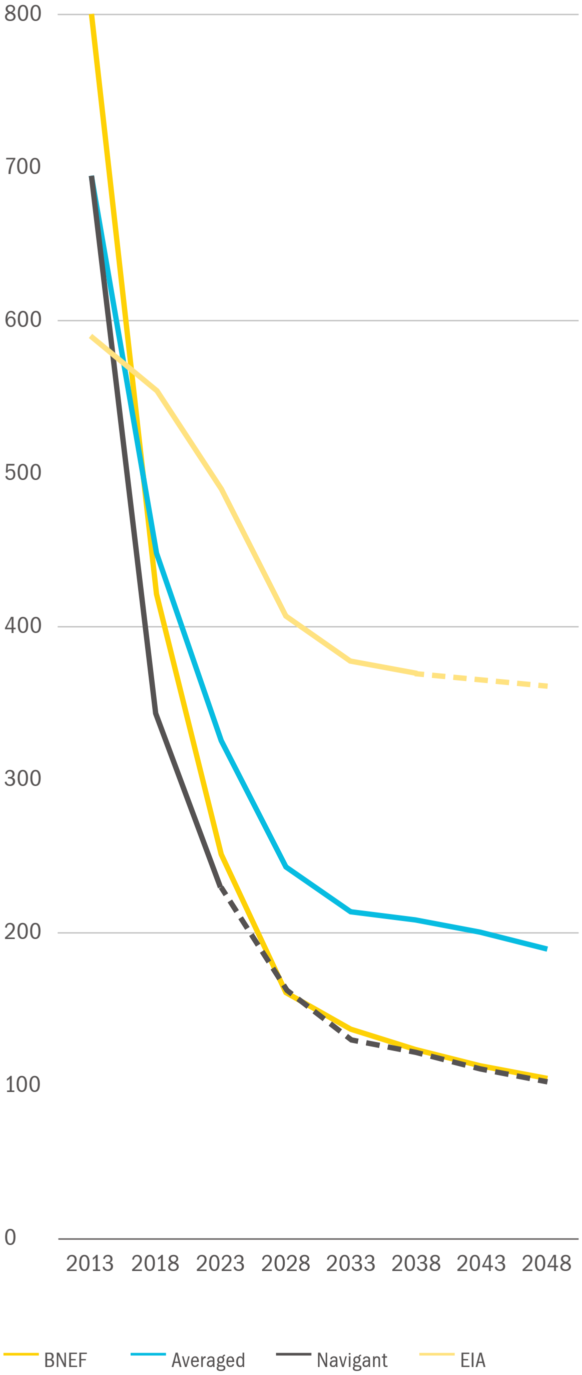
Most battery systems still cost over EUR 800/kWh, though in April 2015 the US-based company Tesla announced a new, cheaper module at USD 500/kWh after inverter costs and installation. Despite the benefits of high self-consumption, the total costs of the solar PV system will remain higher in the near term. However, the battery price will fall quickly. By 2025, the price of batteries is projected to drop below USD 200/kWh, as shown in figure F.

Currently, battery storage would add another USD 0.14/kWh to the LCOE, but this is expected to drop to only USD 0.02/kWh within five years. In Germany, in fact, household solar PV and battery storage will reach grid parity by 2016.

Demand-side management techniques in the home will also raise self-consumption levels. SMA and other inverter companies are already offering solutions that predict power output based on weather forecasts, and which automatically start electricity-intensive appliances like washing machines when power production is optimal. These demand-side tools are reported to increase self-consumption rates to 45%. Solutions which connect smart systems to storage are also arising. EDF, for example, has proposed the use of boilers as a cheap means to store PV-produced electricity, leveraging its Linky smart metering technology to make

F

BATTERY PRICE PROJECTIONS [USD_{2012}/KWH]



Source: BNEF, Navigant, EIA, Rocky Mountains Institute, Roland Berger

use of the 11 million boilers in France that partially rely on the grid.

With affordable storage and home automation in place, self-consumption rates of solar PV, adoption rates, and the profitability of the system as a whole are expected to rise.

4. New commercial developments

A solar PV system is characterized by large capital expenditures and very limited operational costs. Because many households and SMEs do not have the capital needed upfront, several players have set up various financial solutions. For instance, Sungevity or DZ-4 and similar companies offer solar PV systems, leasing the system to the homeowner in either a financial or operating lease. Utilities in Europe also offer lease constructions, receiving reimbursement for the system via the utility bill. US firms are even moving to Europe to offer their products for these leasing schemes, and new European companies are arising as well. In addition to reducing the electricity bill, one of the key arguments for households to lease a solar PV system is the guarantee on revenues and maintenance costs for a product with a lifetime of more than 15-20 years. Also, the risk of shorter longevity is carried by the leasing company. Nevertheless, the majority of European households still opt for buying their own system; adoption of leasing is more common in the SME segment.

The ease of buying solar PV systems has also improved. In the early days, a local installation company would install the solar PV system. Nowadays, via websites and apps, utilities provide a quote for installation which includes revenue projects based on satellite pictures of the rooftop. IKEA also now offers installation of solar PV systems. Solar PV is coming more and more in reach for the average household.

These commercial developments are lowering the hurdles for household and SME purchase of a solar PV system. Paired with greater knowledge about these systems and the "keeping up with the Joneses" effect, commercial dynamics will ensure continued solar PV adoption.

Solar PV penetration will be high around the world, including in Europe

Due to solar PV's declining costs in the utility, commercial and residential segments, its installation will become profitable, even without subsidies. In the absence of subsidies, the growth path will become more stable. No more "boom and bust cycles" – sudden changes in government policy – will cause the large interruptions seen in various countries in the EU, Japan and the United States over the past years.

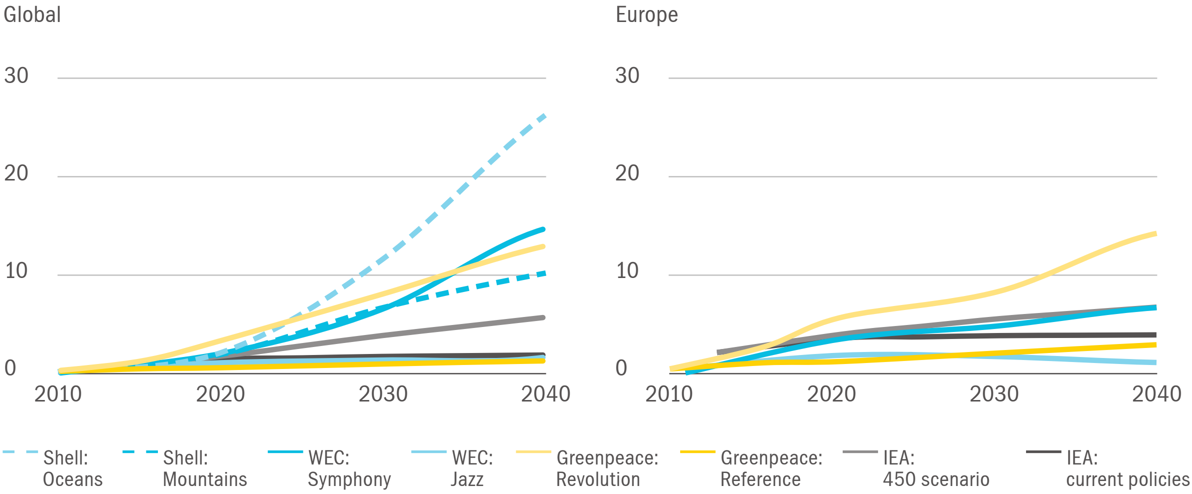
Most LCOE forecasts for electricity from solar PV predict that grid parity will be reached for utility-scale and residential use. Using price forecasts for solar and alternative energy sources, most institutes have developed energy scenarios for the share of solar PV in total electricity production. Figure G demonstrates that these penetration rates vary substantially depending on the assumptions made.

In its oceans scenario, Shell is the most optimistic with a penetration rate of more than 25% worldwide. The IEA is the least optimistic, with a rate of max 5% in its World Energy Outlook. However, in its Energy Technology Perspectives report it predicts a rate of 16% in its high renewable variant of the "2 degrees" scenario.

These energy scenarios reveal a pessimism for the uptake of solar PV. They assume high LCOEs for the near future, and their capital cost projections for 2020 and 2035 were actually already reached in 2013. These energy scenarios are often developed from the perspective of optimizing the energy system, while the decision to buy a solar PV panel is often made by households with the aim of reducing their energy costs and they do not take externalities into account.

G

SHARE OF SOLAR PV IN TOTAL ELECTRICITY GENERATION BY ENERGY SCENARIO [TWH %]



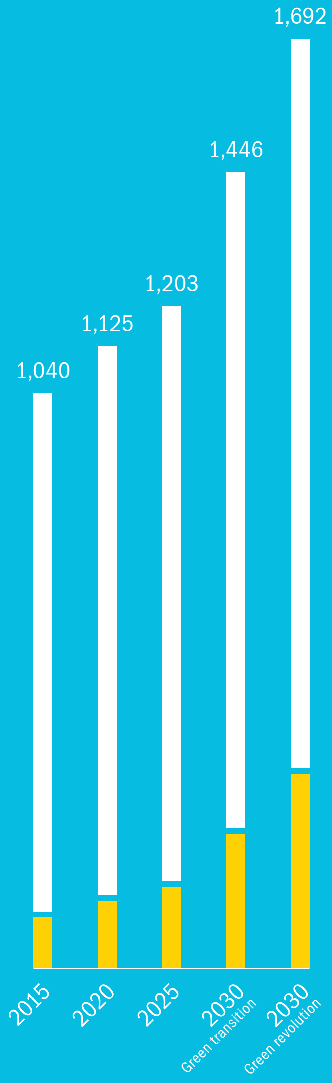
Source: IEA, European Commission DG TREN, Shell, WWF, Greenpeace, WEC, Roland Berger

H

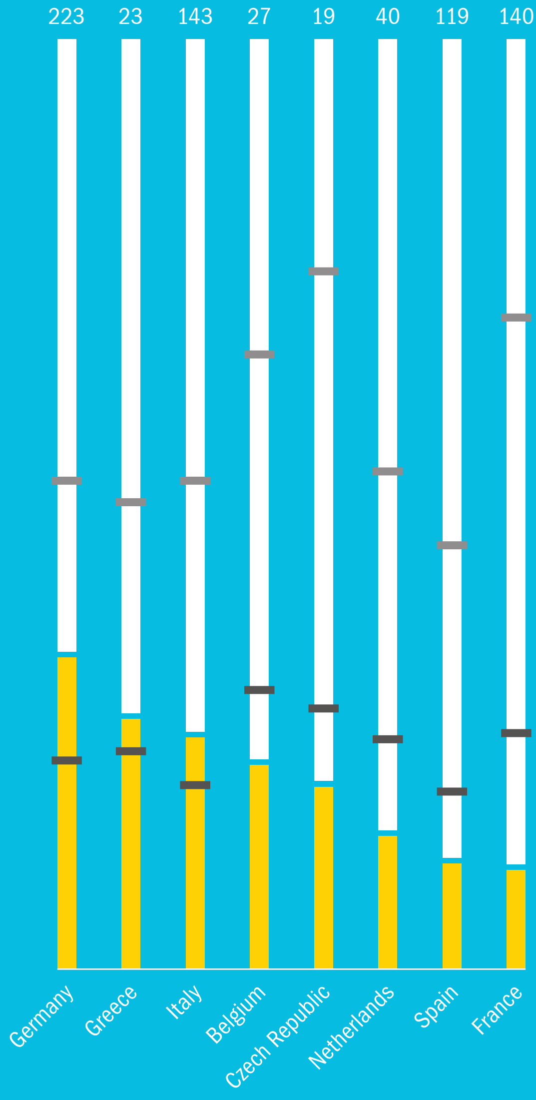
SHARE

SHARE OF SOLAR PV IN EUROPEAN GENERATION CAPACITY

Generation capacity[1)] in ENTSO-E area [GW]



Generation capacity and base and peakload demand in 2025 [GW]



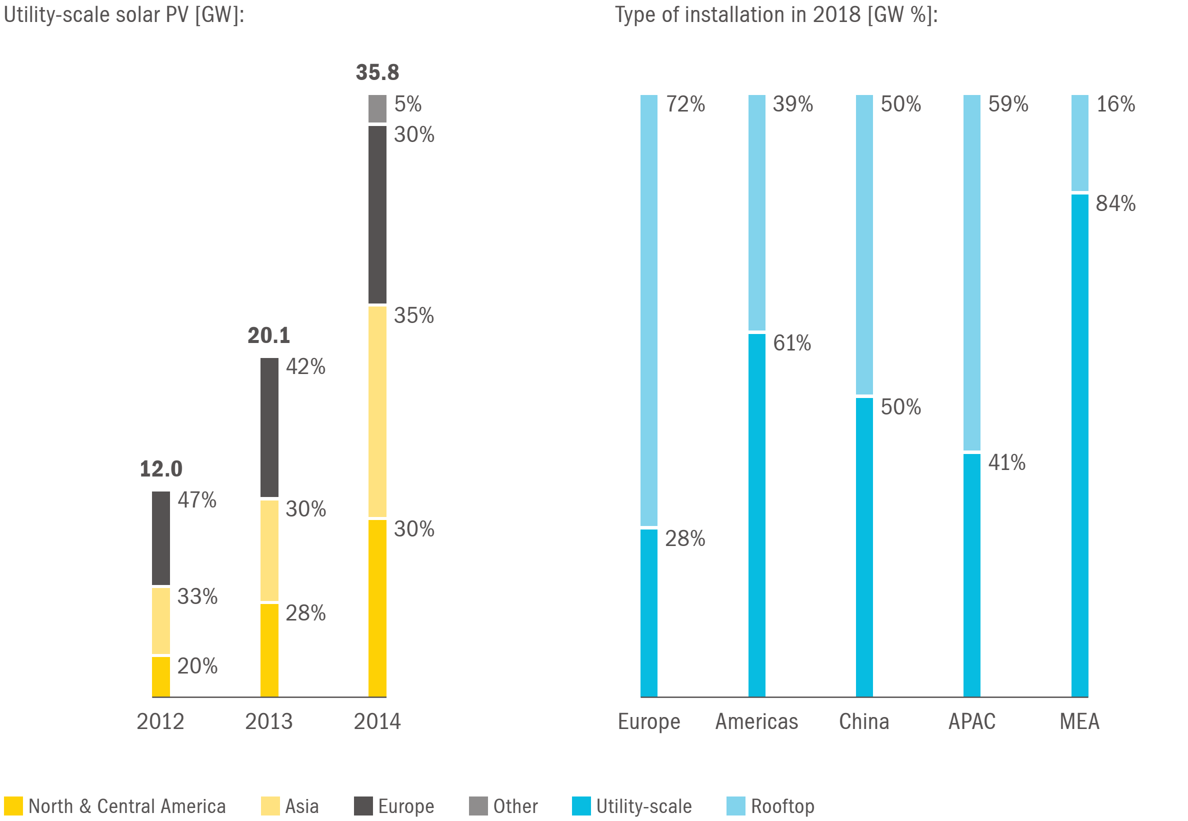
Solar Other Baseload demand Peakload demand

1) Scenario B of ENTSO-E system adequacy report; UK data taken from the slow progress scenario in the National Grid Future Energy report

Source: ENTSO-E, National Grid, Roland Berger

I

SOLAR PV INSTALLATION BY TYPE



Source: Wikisolar, EPIA, Roland Berger

We believe that the forecasts and visions of the European transmission system operators are more in line with future generation capacity in Europe, as shown in figure H. European TSOs assume higher adoption rates of solar PV; by 2025, Europe's solar PV generation capacity is forecast at 12% or 147 GW. In ENTSO-E's green revolution scenario, solar PV might even reach 21% of installed capacity, or 12% of consumption, by 2030.

The higher share predictions reveal that solar PV can have a drastic impact. In Germany, Greece and Italy, solar PV capacity will already exceed baseload demand by 2025. It could even exceed 50% of peak-load demand, making export and storage necessary to deal with the market situation.

In contrast to other regions in the world, the adoption of utility-scale installations will be lower in Europe, where more will be built in Southern European than in Northern Europe. Lower irradiation factors in Europe hinder reaching grid parity in this segment, and local and national European governments often take a negative stance towards utility-scale solar. Investors and other project developers own the utility-scale installations in Europe. With a share of less than 1% in total solar PV capacity, solar PV is a gap in the production portfolio of traditional utilities. I 1

Utilities will have to adapt their business models to solar PV

The rise of solar PV will affect utilities in a number of ways, including reductions in volume and peakload prices. Higher intermittency may affect the ability to operate power plants, and as a consequence new pricing models in the electricity sector will have to be developed.

1. Lower volumes in specific segments

In the European Union, solar PV systems will be mainly owned by households and commercial players, including agriculture. Together, they will produce 9-12% of total electricity consumption in the EU by 2030. Utilities will have to reduce electricity production at their power plants by at least the same amount.

The residential and commercial segments are responsible for almost 60% of total electricity consumption. With its higher margins, these segments also constitute the more attractive markets for utilities. Margins are lower in the industrial segment, where prices are close to wholesale and where consumption profiles and prices reflect the baseload production. Solar PV will thus replace between 5% and 1% of the more attractive market segments, as seen in figure J.

Solar PV's replacement of utility production and its share of the residential and commercial segments differ by country. In Italy and Spain, solar PV could account for 33-47% of power volumes in the residential and 26-46% of volumes in the commercial segment. In France, replacement will be lower at 10-17%.

While solar PV could replace almost 14% of European utility power production on average, it will not fully replace 14% of the revenues from utilities. Self-consumption is currently at 20-30% and could increase to 50%, and the excess electricity needs to be bought by market players. Utilities, already with access to these consumers, are in a good position to buy and sell the excess electricity and thus increase their trading activities. Utilities can also leverage their storage solutions, which have longer cycles than same-day batteries.

2. Intermittency will impact pricing

In contrast to conventional electricity generation, solar PV cannot be dispatched. Electricity is generated whenever the sun shines. Ultimately, this will impact conventional electricity generation, which will have to adapt its production, due to solar PV's absence of marginal costs. Solar PV will always push out more expensive electricity generation options.

The production of solar PV is highest between noon and 2pm, when irradiation is highest. Production swings will also occur due to weather conditions. With higher installed capacities of solar PV, the impact of the day/night profile and weather conditions will affect the utilization of conventional electricity. Large weekly and seasonal effects will also be present. A single week could see a tripling of daily production, simply due to weather. Production can also be eight times higher in summer than in winter. K

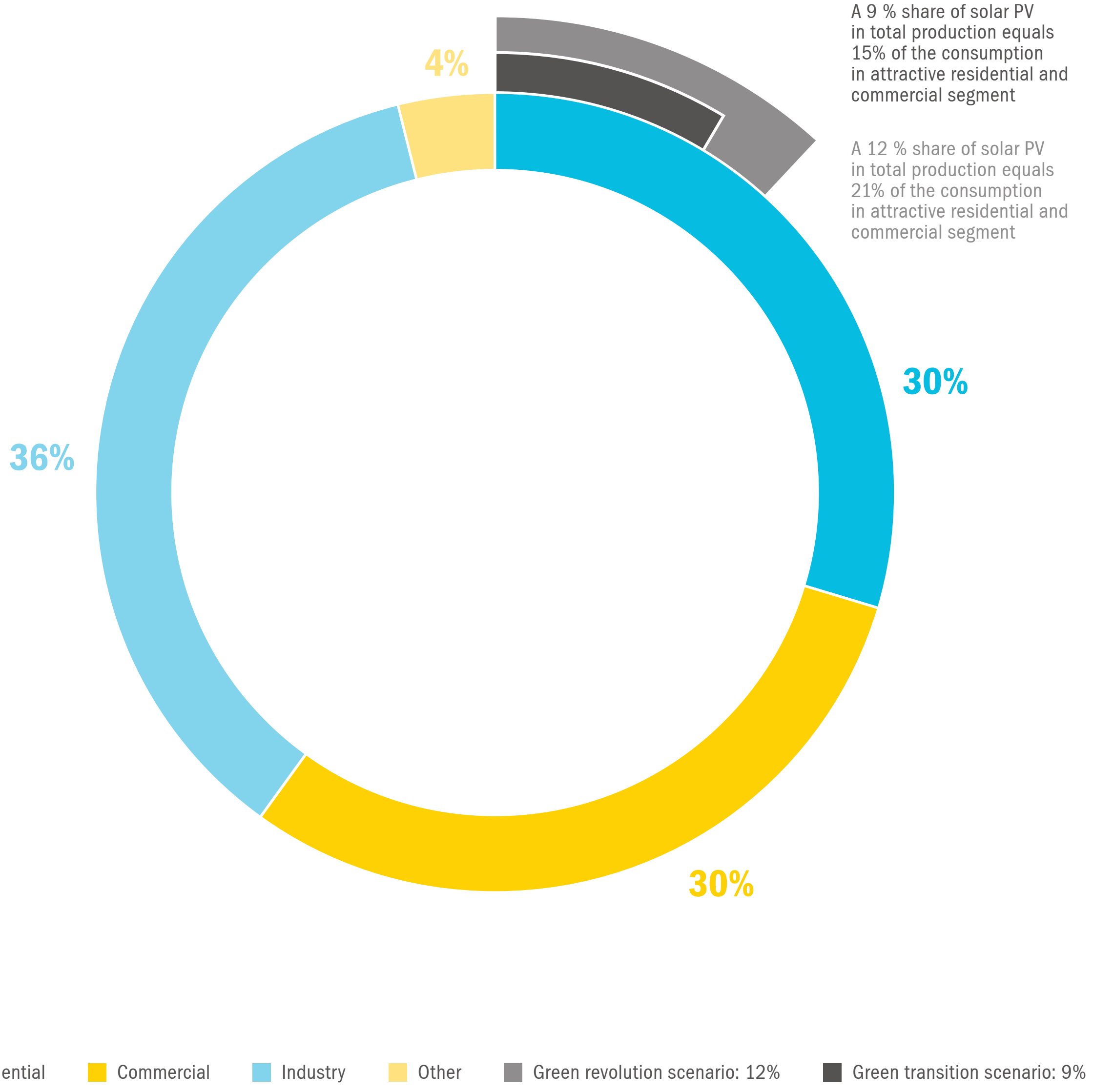
This intermittency presents both challenges and opportunities for utilities, which will have to complement solar PV production while dealing with changed electricity prices. For example, the intermittency requires utilities to be able to quickly respond to fluctuations. Household use of batteries might partially offset the impact of daily fluctuations, but not seasonal.

J

2 ELECTRICITY CONSUMPTION IN 2030

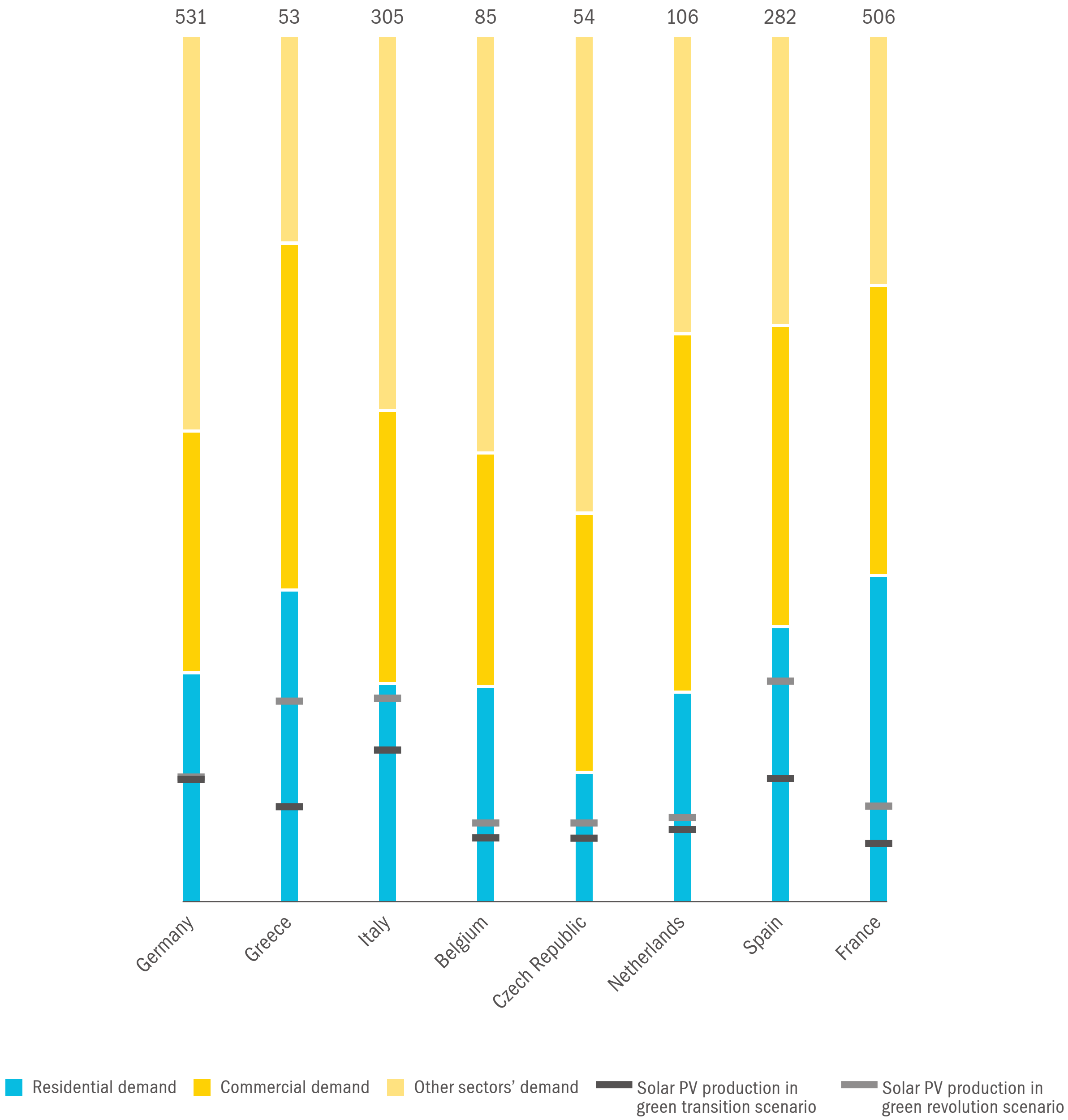
EU ELECTRICITY CONSUMPTION BY SEGMENT [TWH %]

∑ 3039 TWh



Source: ENTSO-E, Eurostat, EU DG Energy, Roland Berger

ELECTRICITY DEMAND BY SECTOR & SOLAR PV PRODUCTION [TWH]



With an increasing intermittent share in power production, the ability to deliver power when it is needed, rather than the volumes delivered, will become more important. Utilities, in turn, can price the access to capacity, rather than the energy itself.

Power plants with large ramp-up times may not be able to meet daily changes in demand, and less efficient gas turbines might be used more often to fill in the gaps. Seasonal variances would also vary the need for power plants. Power plants, which as a backup will see lower load hours, may need to have new characteristics to accommodate the intermittency. The balance between baseload and peakload power plants will change.

Solar PV production is highest in the middle of the day, when power demand is also generally at its highest. This production peak has almost no marginal costs, and will thus drive out the more expensive production sources, lowering peak prices in turn. Lower peak prices will reduce the revenues of gas-fired power plants, which will also experience fewer load hours – a situation that many gas-fired power plants in Europe are already facing. By orienting the solar PV panels in a different configuration, utilities and independent power producers are now optimizing solar PV output during peak hours and obtain best prices and they do not aim for maximum total production.

Figure L depicts a simplified merit order for Germany in 2015 and 2030. Solar PV and wind clearly overtake gas-fired power plants. Conventional capacity will see lower volumes and generally lower prices, reducing its ability to earn back the fixed costs of installations. Coupled with wind power, which also has no marginal costs, electricity prices could well become negative once solar PV and wind production exceed baseload demand.

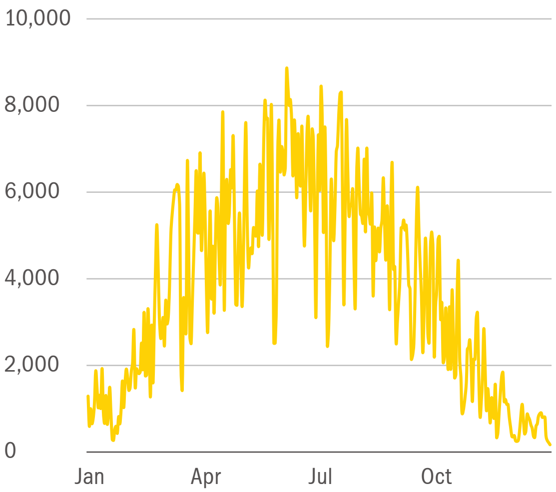
3. New business models for utilities

As consumers rather than utilities will increasingly make the investment decision, without considering the implications on a country's power production portfolio, solar PV's share in the energy mix will grow over time. Utilities will have to adapt their business models to accommodate this growth and the more intermittent need to match power supply with demand, to tackle the challenges presented in this new economy and seize its opportunities.

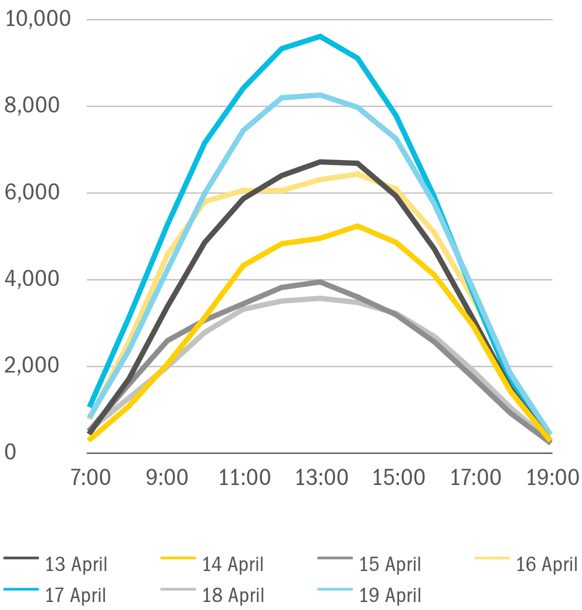
K

SOLAR PV PRODUCTION IN GERMANY IN 2014

Daily solar PV production in Germany [GWh]



Hourly solar PV production in German TenneT area, April 13-19, 2014 [MW]



Source: EEX, Bloomberg, Roland Berger

With an increasing intermittent share in power production, the ability to deliver power when it is needed, rather than the volumes delivered, will become more important. Utilities, in turn, can price the access to capacity, rather than the energy itself. The large seasonal production variations will also ensure that household and SME reliance on utilities will continue. Utilities can offer products that combine services for solar PV systems with providing an adequate energy supply. This also creates an opportunity for utilities to differentiate their offers, where storage, capacity access and power supply are bundled. Packages can thus be tailored to the consumption profile of the household or SME.

Another area of opportunity lies in the excess electricity from households and SMEs that will have to be marketed. Given their long-established access to these consumers, utilities can play a pivotal role in this new electricity trade. In a simple model, a utility can buy excess electricity from a household at a fixed price and take all the marketing risks. In a more complex model, a utility can offer the consumer access to a trading platform, where the consumer can sell power on a local or national power exchange, similar as the current offers for combined heat power systems in greenhouses operated by Dutch horticulturists.

From these possibilities, it is clear that the new business models for utilities will shift from providing electricity to matching supply and demand, and to the delivery of security in the energy supply.

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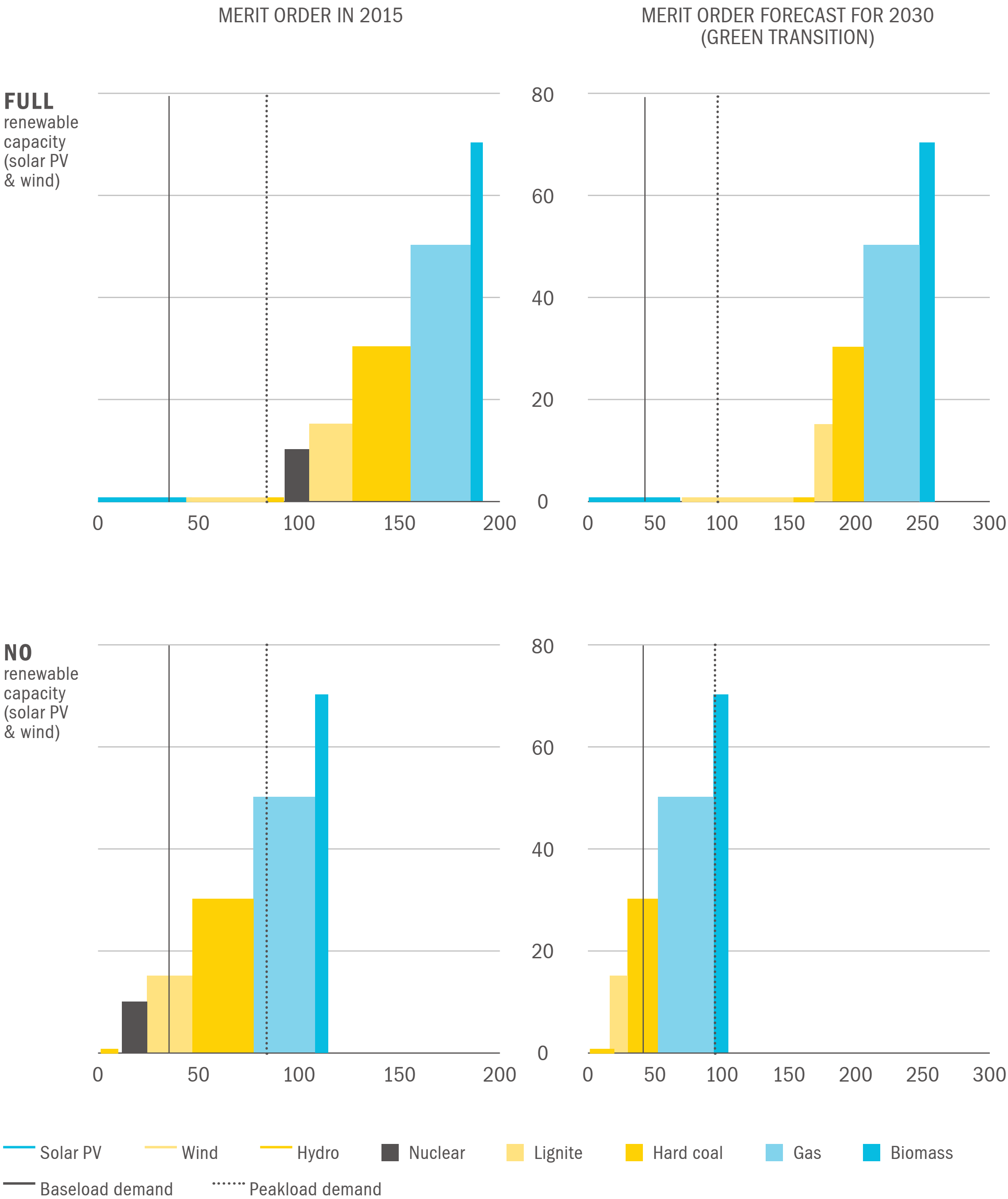
SIMPLIFIED MERIT ORDER FOR GERMANY [EUR/MWH]



Source: RWE, Roland Berger

Transmission and distribution system operators have to prepare for intermittent and decentralized electricity from solar PV

Solar PV will not only affect utilities; its intermittency and volume-reduction effect will also impact transmission and distribution system operators (TSOs and DSOs) as production becomes less centralized.

Decentralized solar PV generation will reduce transport volumes, especially on the transmission grid which mainly serves large power plants and industrial clients. DSOs will be somewhat less affected, as the excess electricity will be distributed mainly via the distribution grid. Nevertheless, the grid must always be able to deliver electricity and meet demand, even when solar PV production is low. As the cost structure of the grid limitedly depends on transported volumes, the introduction of a capacity tariff may be necessary to maintain the grid and share the costs equally between its users.

Decentralized generation will also lead to changes in the structure of the transmission grid. The grid has been built to transport power from large central power plants to the end-users. With solar PV, production will also take place in consumption areas, which may require changes in the grid and its power flows. This scenario can be compared to the Dutch greenhouses and their CHPs, where consumption areas became production areas, leading to changes in the grid. Such investment costs will have to be borne by the end-user. DSOs will also have to change their grid structure to accommodate the injection of excess electricity. The production peaks between noon and 2 pm may also require reinforcement of the grid; local grid storage solutions may become a lower-cost alternative to such reinforcements. Electric vehicles and their batteries could balance the grid to a significant extent. Still, excess power production in a certain area may require injection of electricity from the DSO into the TSO grid. Again, such costs will have to be borne by the end-user.

The combination of centralized and decentralized power production and intermittency will increase the complexity of maintaining grid balance. Smart meters and more grid measuring systems will be needed to track the power flows and operate the network efficiently. Demand-side management systems will become crucial to grid operations and the accommodation of the fluctuations in power supply. TSOs and DSOs will have to strengthen their roles as market coordinator and power clearinghouse, and fully exploit the opportunities that lie in wait in a smart grid.

Conclusions

Worldwide, solar PV will develop into one of the main electricity generators in the energy mix. Its costs will continue to decline. For households and SMEs, it will become a cheap alternative to conventional grid power, and on a utility-scale it will compete with other power generation options. New supportive technologies, like batteries and demand-side management technologies, will drop in costs as well, making solar PV even more attractive and further raising its penetration rates. In the European Union, solar PV production will equal 10-14% of total power consumption by 2030. In certain European countries, solar PV production could even reach 50% of household and commercial consumption.

Solar PV will change the utility industry. The utilities' role of centralized production will evolve from delivering volumes to providing access to electricity capacity. The intermittent nature and decentralized production of solar PV will require them to improve in the areas of matching demand and supply and ensuring supply security. Maintaining balance and a functioning grid capable of dealing with multidirectional power flows and power trade will change the nature of the network companies.

Utilities will have to change their production portfolio. Power plants must become more adaptive to supply and demand variation and be able to fill in the gaps. Pricing models, in turn, should be based on capacity rather than on production. Matching power demand and supply will become a key business area, and utilities will have to develop models to support trade from decentralized production. Furthermore, with solar PV bringing about a need for new and more complex products and services for households and SMEs, utilities are ideally positioned to pull such offerings into their portfolios.

Grid operators will have to adapt their networks to accommodate the decentralized production and shifts in power flows. Capacity pricing models will become important to DSOs. Installation of smart meters and other network measuring systems will become crucial to efficient grid operations and the delivery of security of supply. TSOs and DSOs will have to strengthen their role as a clearinghouse for power flows. Furthermore, TSOs must prepare for different power flows and lower volumes, leading to fundamental changes in the grid setup.

ABOUT US

Roland Berger Strategy Consultants

Roland Berger Strategy Consultants, founded in 1967, is the only leading global consultancy with German heritage and of European origin. With 2,400 employees working from 36 countries, we have successful operations in all major international markets. Our 50 offices are located in the key global business hubs. The consultancy is an independent partnership owned exclusively by 220 Partners. **WWW.ROLANDBERGER.COM**

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In their study, "Advancing Europe's energy system: stationary fuel cells in distributed generation", the consultancy Roland Berger Strategy Consultants and the Fuel Cells and Hydrogen Joint Undertaking explore the commercialization prospects for stationary fuel cells. Jointly authored by 35 industry stakeholders, the study presents the most far-reaching and comprehensive analysis of stationary fuel cells in Europe to date.

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