

The following is a redacted version of the original report. See inside for details.

NEXTGEN POWER

Solar to transform Europe's energy mix

Solar costs have plummeted by 80% since 2010, which is game-changing for power markets as it removes the main obstacle preventing renewables from dominating the energy mix: the cost of energy from large-scale PV plants is now lower than that of conventional fossil fuel plants. The economics for solar are particularly compelling in Spain, which we consider the precursor of a structural trend that's likely to spread across major markets globally. Improved economics, in conjunction with the rise in corporate offtakes (PPAs) and potentially higher EU 2030 renewable targets, could accelerate the process beyond consensus expectations. We forecast that this structural shift will disrupt legacy generation, and see a sizeable c.15%-40% earnings risk by 2030E for the most exposed names across Europe.

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Note: The following is a redacted version of “NextGen Power: Solar to transform Europe’s energy mix” originally published May 2, 2018 [50pgs]. All company references in this note are for illustrative purposes only and should not be interpreted as investment recommendations.

NEXTGEN POWER: SOLAR IN NUMBERS



80%

Reduction in solar costs since 2010.

30%-50%

Reduction in solar LCOE we forecast by 2030.



45%

Discount of 2018E solar LCOE vs. forward curve in Spain.

24 GW

Requests for grid connections in Spain for large solar PV projects, equivalent to c.25% of the total installed base (plus 20GW of wind requests).



c.15%-40%

EPS risk for the most exposed names, by 2030.



20%-40%

Downside risk to power prices across Europe by 2030.



c.1.5%

Current solar output share in global energy mix.



60%

Implicit share of renewable output in the power mix suggested by the European Parliament's proposal, vs less than 30% today.

Executive Summary

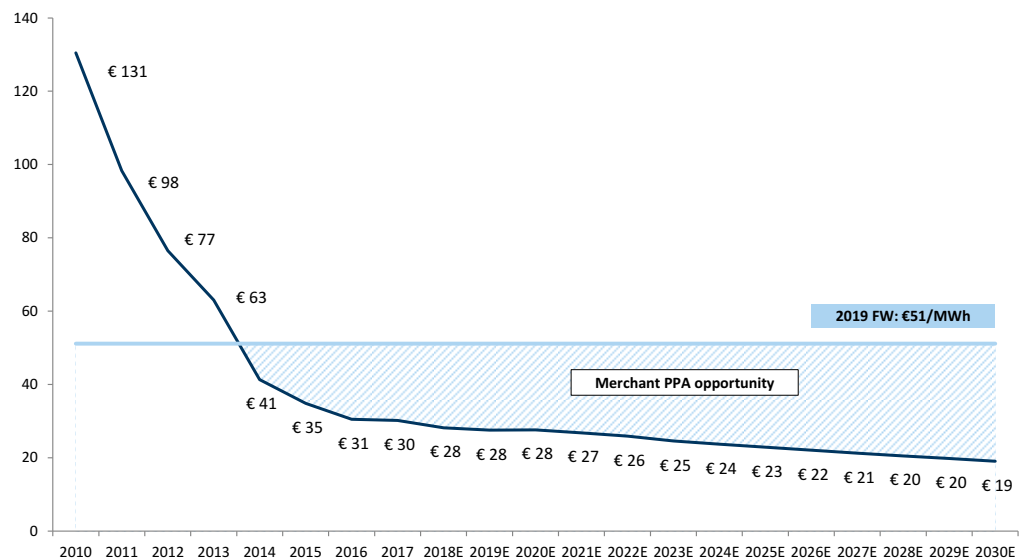
Solar costs have plummeted by 80% since 2010; that’s game-changing for power markets as it removes the main obstacle preventing renewables dominating in the energy mix: the cost of energy from large-scale PV plants is now lower than that of conventional fossil fuel plants. The economics for solar are particularly compelling in Spain, which we consider the precursor of a structural trend which is likely to spread across major markets globally. What makes Spain well-suited for solar is the combination of three “highs”: high irradiation, high power prices and high amounts of spare generation capacity. Improved economics, in conjunction with the rise in corporate offtakes (PPAs) and potentially higher EU 2030 renewable targets, could accelerate the process beyond consensus expectations. We forecast that this structural shift will disrupt legacy generation, and we see c.15%-40% earnings risk by 2030E for the most exposed names across Europe.

Solar economics continue to surprise: LCOE 45% below forward curves

Since 2010, levelised costs of energy (LCOE) for large-scale solar PV have fallen by c.80%, and we estimate the trend is set to continue owing to cheaper equipment costs, lower opex and better module efficiency (ie, higher load factors). In Spain, we estimate solar LCOE at €28/MWh this year, c.45% below the forward curve, and expect it to drop to €19/MWh by 2030. Although the absolute LCOE levels will vary by country, we forecast the same reduction trend across Europe; the economics are particularly compelling – for now – in Spain and Italy.

Exhibit 1: Spain’s solar LCOE is c.45% below forwards and will keep declining

Spain: Solar PV LCOE evolution vs 2019 power forward, €/MWh



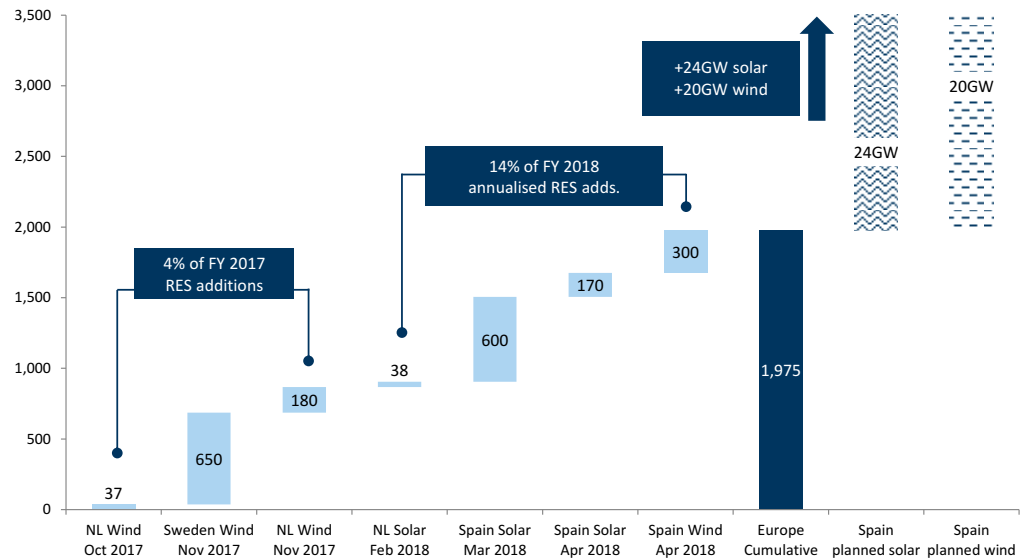
Source: Goldman Sachs Global Investment Research, Bloomberg, IRENA

Corporate PPAs likely to accelerate the shift to renewables

Similar to what has been happening in the US (where in 2017, corporate PPA volumes amounted to nearly 20% of the RES additions), European corporates have started to sign long-term power offtakes from renewable sources. Year-to-date, about 10% of renewables (RES) additions have come under corporate PPAs. We believe this new tool (C-PPA) will keep gaining momentum and could accelerate the development of solar PV (and wind): it is one of the reasons behind the 24 GW of PV projects currently under development in Spain (plus 20 GW of wind).

Exhibit 2: We believe 2018 could be a turning point for corporate PPAs in Europe

Major corporate PPA contracts signed in Europe since 2017 (MW)

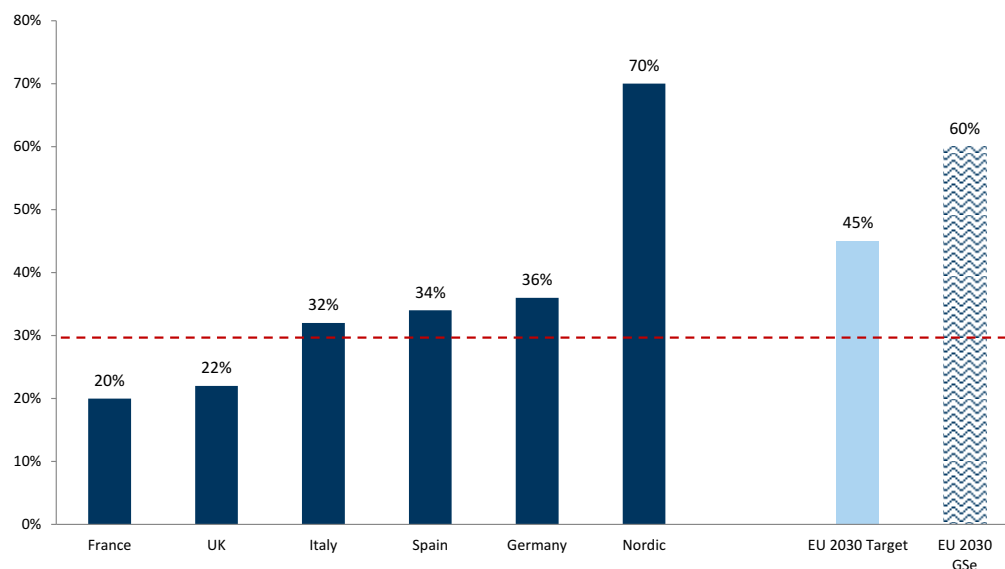


Source: Company data, Goldman Sachs Global Investment Research

EU 2030 renewables targets have upside risk

The European Parliament has suggested raising the 2030 renewable energy target from 27% to 35%, motivated by improved economics. Considering some pushbacks by the Council, we assume that the final outcome might settle at 30%-32%, based on similar EU decisions. Since the current target implies a 45% share for renewable electricity generation by 2030, we estimate that under a revised 35% target, the share of renewable electricity would need to increase to 60% - or nearly double vs the current EU-28 average of c.30%.

Exhibit 3: EU 2030 upgraded targets could imply significant upside to Europe's demand for renewables
Renewables penetration as % of total electricity generation (2017) vs EU target and EP proposal



Source: Eurostat, Goldman Sachs Global Investment Research

Legacy generation: 15%-40% of earnings at risk for most exposed names

Currently, legacy generation assets account for about 15% of sector EBITDA (vs >40% at their 2010 peak). We estimate that, by 2030, legacy generation EBITDA could face 30% downside risk. Although equivalent to “just” c.5% of sector EBITDA, the impact would be concentrated in a handful of companies.

Spain the early mover; Italy to follow, the rest much later

When estimating how soon a country may be impacted, we observe: i) irradiation levels, ii) regional power prices, iii) presence of spare/backup capacity, iv) grid bottlenecks, v) energy policy. Based on this framework, Spain would appear the early mover (visible impact by 2023-25); Italy could be second (2025-27), while France and the UK would see threats during 2027-30 (Germany post-2030, owing to large-scale closures in legacy capacity and a lower starting point for power prices). We see no threat in the Nordic region, as currently c.90% of the supply is already from fixed-cost, must-run power generation facilities, irradiation levels are lower and as power prices are already the lowest in Europe.

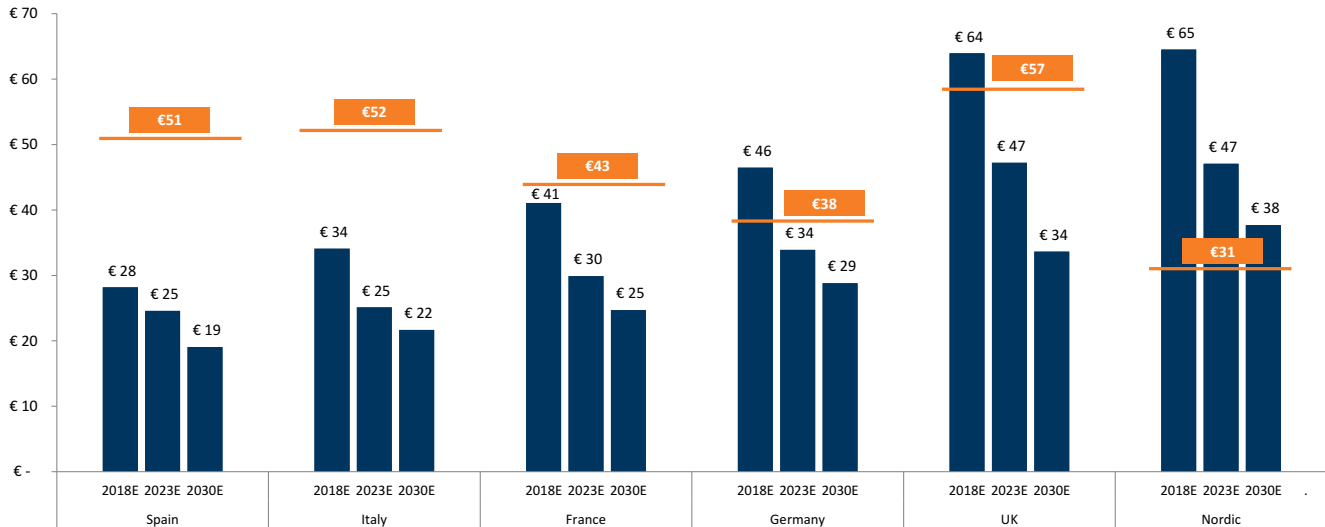
Exhibit 4: Spain and Italy appear to have the best potential for a prolonged boom in Solar PV
 GS framework to assess take-up of Solar PV

	Irradiation Levels	Wholesale Power Price	Grid Status		Shutdowns by 2030	Policy
	(Load Factors, 2023E)	(2019 €/MWh)	Transmission	Distribution	(GW)	
Spain	20%	51			18	Supportive
Italy	18%	53			7	Uncertain
France	15%	43			13	Less supportive
Germany	13%	38			42	Supportive
UK	12%	57			11	Less supportive
Nordic	9%	31			5	NM

Source: Goldman Sachs Global Investment Research

Exhibit 5 shows the vast discount of solar PV LCOE vis a vis the prevailing forward curves across Europe. The gap is particularly wide for Spain and Italy.

Exhibit 5: The spread between LCOEs and forwards suggests that Spain and Italy will be at the forefront of the rise in solar
Solar PV LCOEs vs 2019 forward prices in orange (€/MWh)

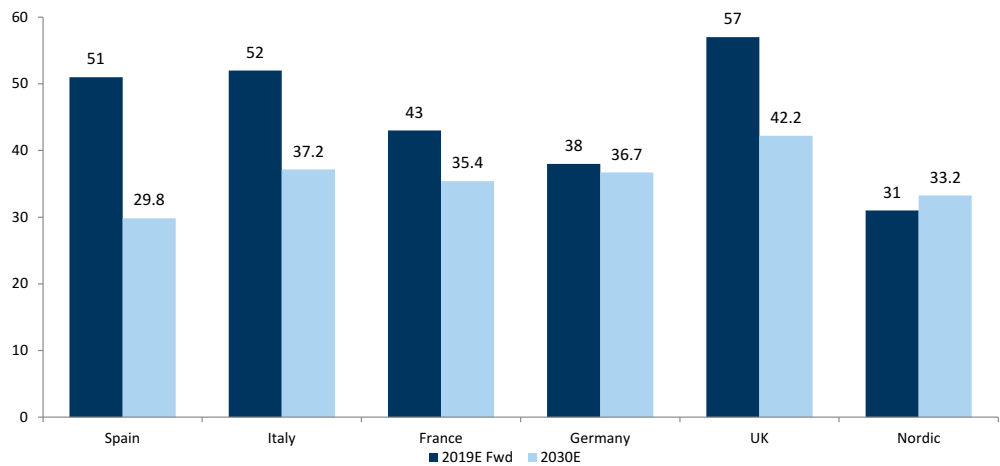


Source: Goldman Sachs Global Investment Research, Bloomberg

Power prices could decline significantly by 2025-30

The rising share of renewables as implied by the European Parliament’s proposal (to nearly 60% of the mix by 2030, a doubling vs 2017) would lead to declining power prices in almost all of Europe. We believe the impact could be particularly severe in Italy and Spain, as explained earlier.

Exhibit 6: Downside risk to power prices in most of Europe owing to the rise in solar (and wind)
2019E forward curves vs our 2030E power price forecast (€/MWh)

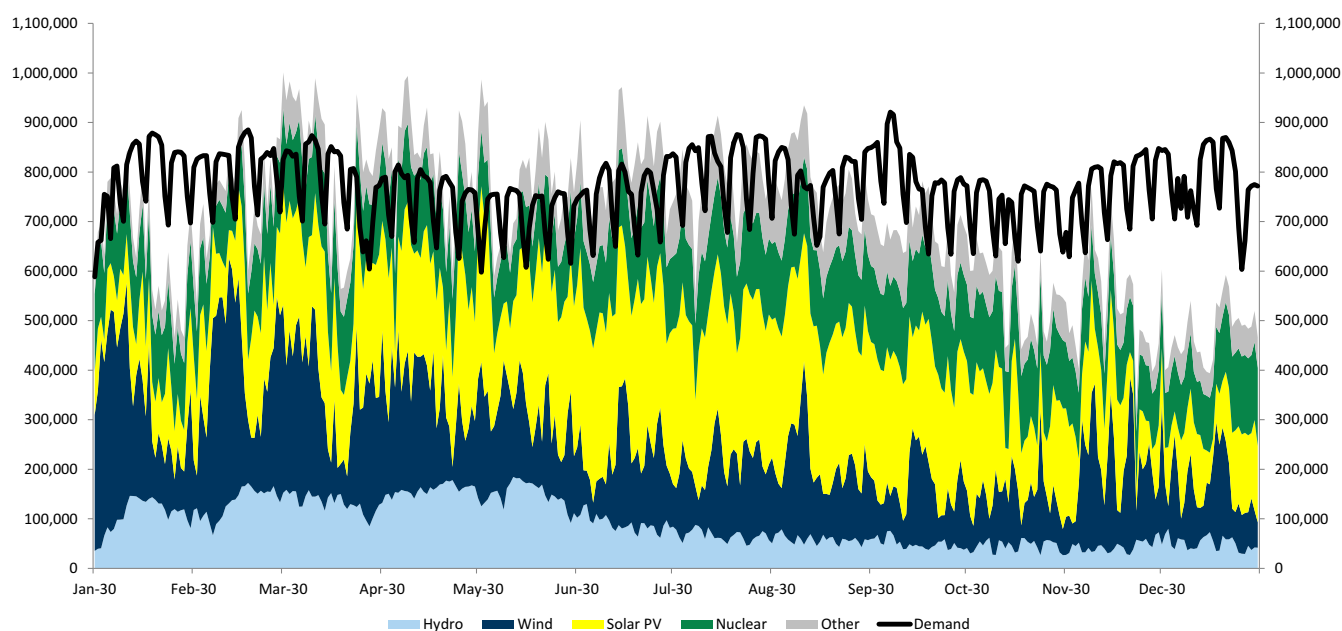


Source: Goldman Sachs Global Investment Research, Bloomberg

The Spanish hourly example. The impact on supply/demand and power prices is likely to be game-changing in Spain. Exhibit 7 shows that must-run technologies (hydro, wind, solar, nuclear, other renewables) would exceed demand about 57% of the time, by 2030. This is likely to imply significant price squeezes in those hours, unless grid-scale batteries are introduced by then, or the EV penetration has significantly picked up.

Exhibit 7: Moving to 60% capacity from renewables would make the market “long” c.57% of the time

Daily generation from “must run” technologies and demand, 2030E (GWh)



Source: REE, Goldman Sachs Global Investment Research

Disruption would likely trigger major industry response

Such a scenario would likely trigger a major response by the industry, in our view, including: (i) consolidation, to gain more exposure to RES, (ii) portfolio reorganisations, to lower exposure to legacy assets, and (iii) step up in RES capex, to offset the earnings cliff.

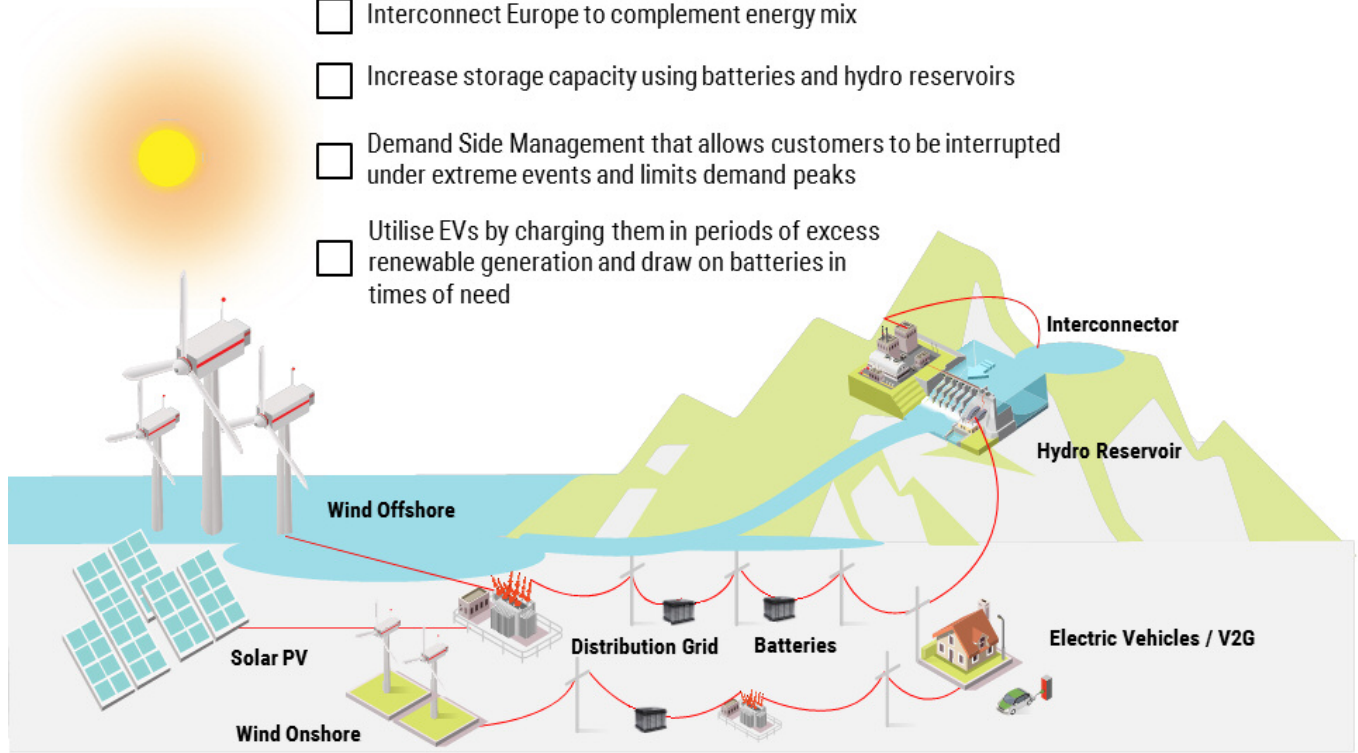
The roadmap to maxing out renewables penetration

This report is the first of a franchise series that will explore the milestones to monitor the rise in solar (and wind) in the power mix, and the move towards 80% electricity from renewables, in line with the 2050 German target. Although renewables could lower power bills thanks to the deflationary pressure on wholesale prices, increasing the share of intermittent supply would also lead to negative externalities and to indirect costs. We mostly believe these will relate to: (i) the digitalisation/expansion of the power grid, (ii) the introduction of storage, and (iii) the need to introduce demand side management.

Exhibit 10: The roadmap to maxing out renewables penetration

New large-scale PV plants and onshore wind projects now produce energy at or below the cost of conventional power stations, while the costs of offshore wind are falling fast as turbines increase in size. Here are the other most important items on the to-do list of what's needed for Europe to max out its renewables penetration:

- Fully digitalise power grids
- Interconnect Europe to complement energy mix
- Increase storage capacity using batteries and hydro reservoirs
- Demand Side Management that allows customers to be interrupted under extreme events and limits demand peaks
- Utilise EVs by charging them in periods of excess renewable generation and draw on batteries in times of need



Source: Goldman Sachs Global Investment Research

The solar industry: Booming for nearly two decades

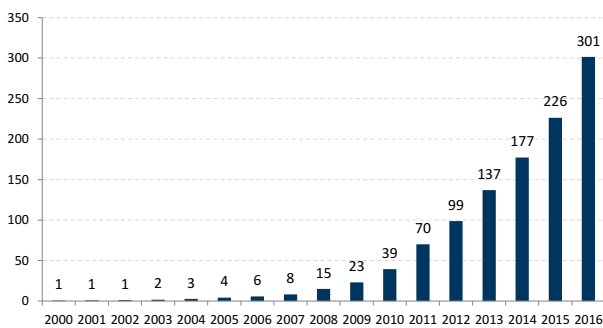
For nearly 20 years, the solar industry has been growing at +c.50% CAGR. Yet, currently solar PV accounts for a mere c.1.5% of the global power output. Estimates by GS and the IEA show that annual capacity additions globally could continue at a 14% pace until 2025-30. Even still, by then, solar PV would still account for a mere 6% of the total energy mix (based on capacity, it would be less than half on output).

Solar capacity additions: +c.50% pa since 2000

Global solar capacity has been growing at a +c.50% rate pa on average since 2000. Growth has slowed in recent years given the higher base but remains at a healthy c.30% per year. Since 2000, the global invested capital in solar has reached above US\$800 bn in 2016.

Exhibit 9: Global PV capacity began growing exponentially in the mid-2000s...

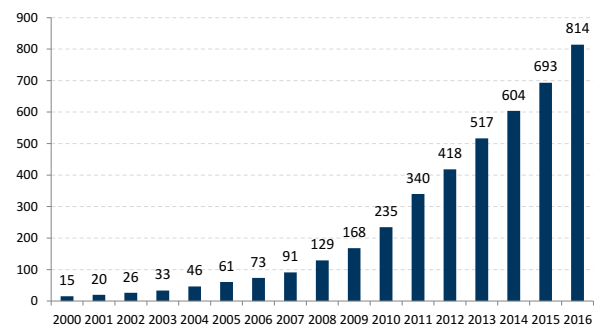
Cumulative solar capacity installed globally, GW



Source: Goldman Sachs Global Investment Research, BP

Exhibit 10: ... transforming solar into a near US\$1 tn industry

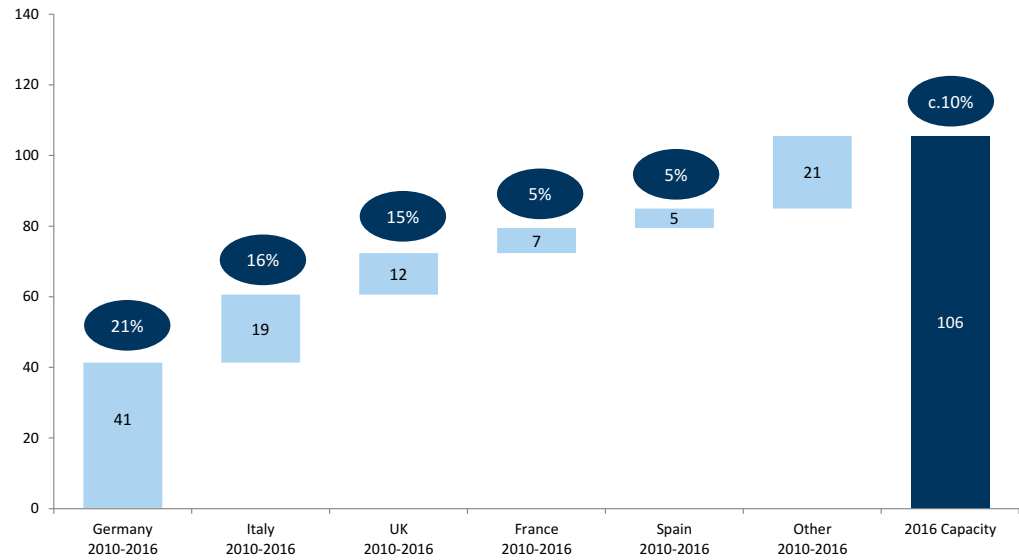
Global invested capital in solar PV installations (US\$ bn)



Source: Goldman Sachs Global Investment Research, BP, IRENA

Europe has led the “solar revolution” and currently accounts for about one-third of the global PV installed base. Germany, Italy and – quite surprisingly given low irradiation levels – the UK have led the effort so far. Spain, as seen in Exhibit 11, has fallen behind.

Exhibit 11: Europe accounts for about one-third of global solar capacity
 European solar capacity additions in GW (bars) and as % of 2016 total generating capacity (ovals)

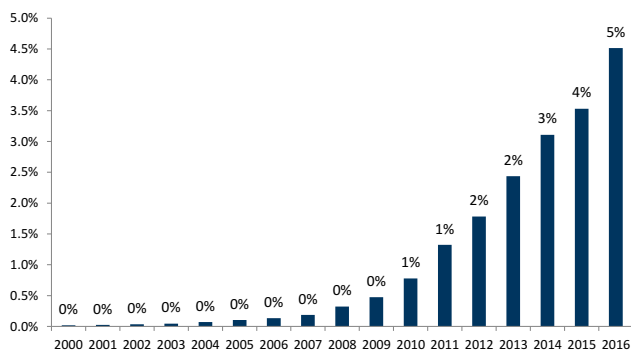


Source: Goldman Sachs Global Investment Research, BP, REE, Terna, RTE, DECC, BNetzA

Solar still just c.1.5% of global energy mix

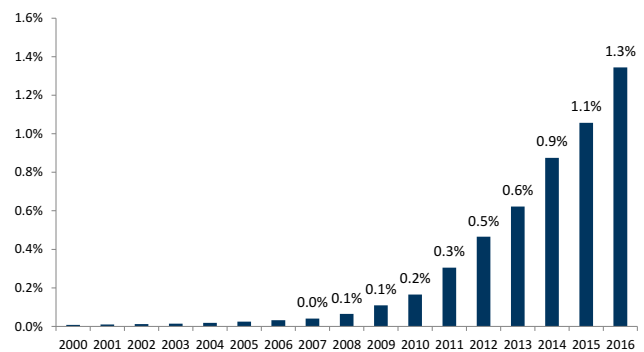
Despite significant growth, solar remains a minor power generation technology globally. Solar capacity now accounts for 5% of total capacity; in terms of share of output, the global market share of solar is less than 1.5%. In Europe, solar accounts for 8% of capacity and 2% of output.

Exhibit 12: Solar accounts for 5% of global installed capacity
 Global solar PV capacity as a % of capacity



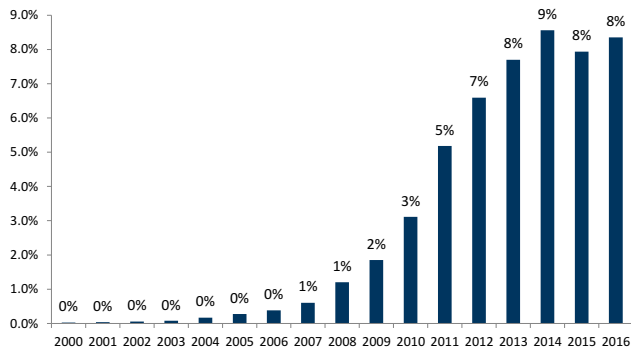
Source: BP, IEA

Exhibit 13: ...and c.1.5% of output
 Global solar PV output as a % of total output



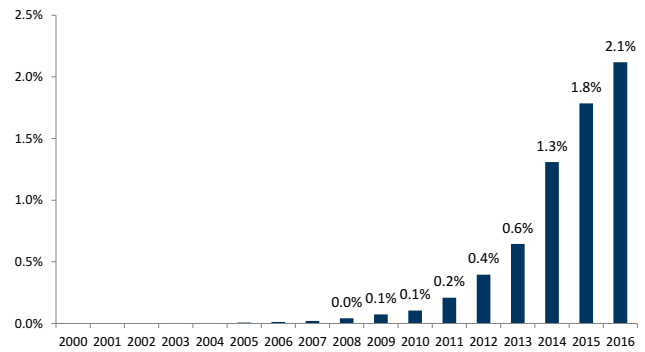
Source: BP, IEA

Exhibit 14: Solar accounts for 8% of European installed capacity...
European solar PV capacity as a % of capacity



Source: BP, IEA

Exhibit 15: ...and c.2% of output
European solar PV output as a % of total output

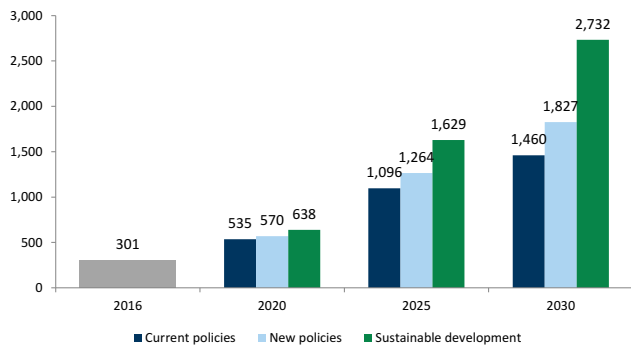


Source: BP, IEA

Growth to 2030 likely to still be c.14% pa

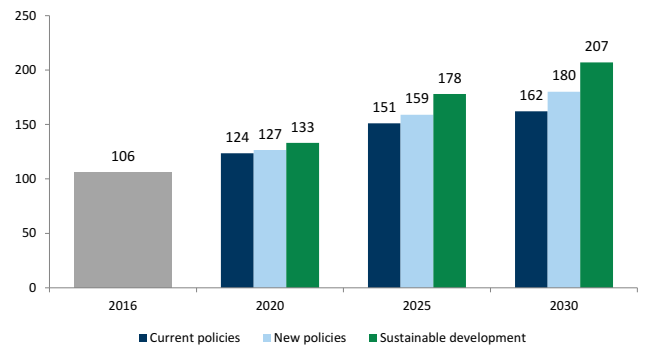
Based on IEA forecasts, we expect sustained solar capacity growth to continue. The IEA expects 12%-17% solar capacity growth pa to 2030, mainly driven by growth outside of Europe. We see upside risks to IEA forecasts, especially in Europe given recent competitiveness gains and announcements in Spain. We also note that the IEA has historically been too conservative with renewable installation forecasts, and has meaningfully underestimated the pace of RES additions globally.

Exhibit 16: Global solar capacity to grow c.14% pa to 2030
Global solar capacity forecasts, GW



Source: IEA

Exhibit 17: European solar capacity to grow 4% pa to 2030
European solar capacity forecasts, GW



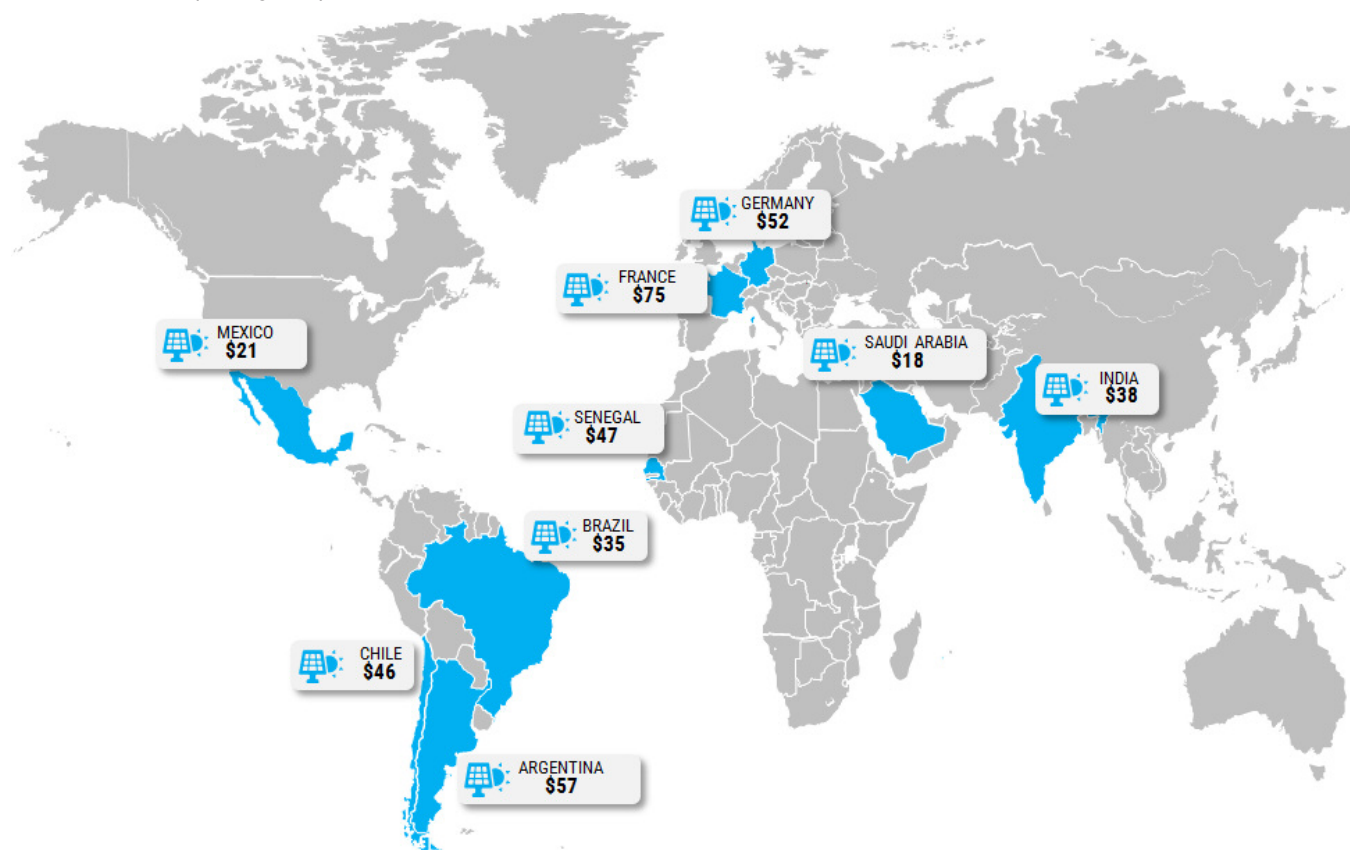
Source: IEA

Solar economics: 80% cheaper than 2010

Since 2010, the solar PV levelised cost of energy (LCOE) has dropped by c.80%. In some countries (eg Spain, Italy), solar LCOE is already substantially below merchant power prices. The decline has been driven mainly by the reduction in equipment costs, which we forecast is set to continue.

Exhibit 20: Solar reached record lows with US\$18/MWh in Saudi Arabia

Latest solar auction prices globally, US\$/MWh

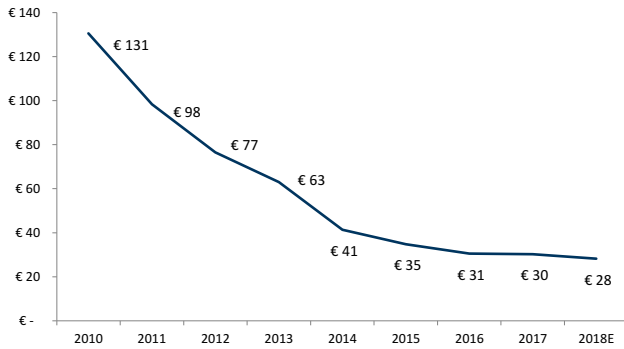


Source: Goldman Sachs Global Investment Research, IRENA, BNetzA, ANEEL

Solar PV LCOE has fallen by 80% since 2010

The significant deflation in solar PV LCOE since 2010 has been driven by a combination of three key factors: (1) lower investment costs; (2) lower cost of capital; and (3) more efficient solar panels.

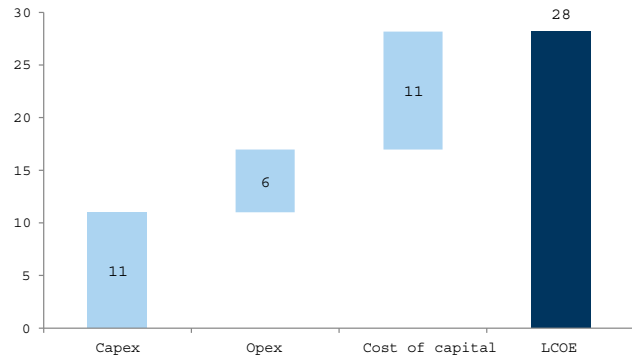
Exhibit 19: Solar LCOE has fallen 80% since 2010
Spain solar PV LCOE evolution, €/MWh



Source: Goldman Sachs Global Investment Research, IRENA

Exhibit 20: Capex and cost of capital are the two main components of LCOE

Spain solar LCOE 2018 split by components €/MWh

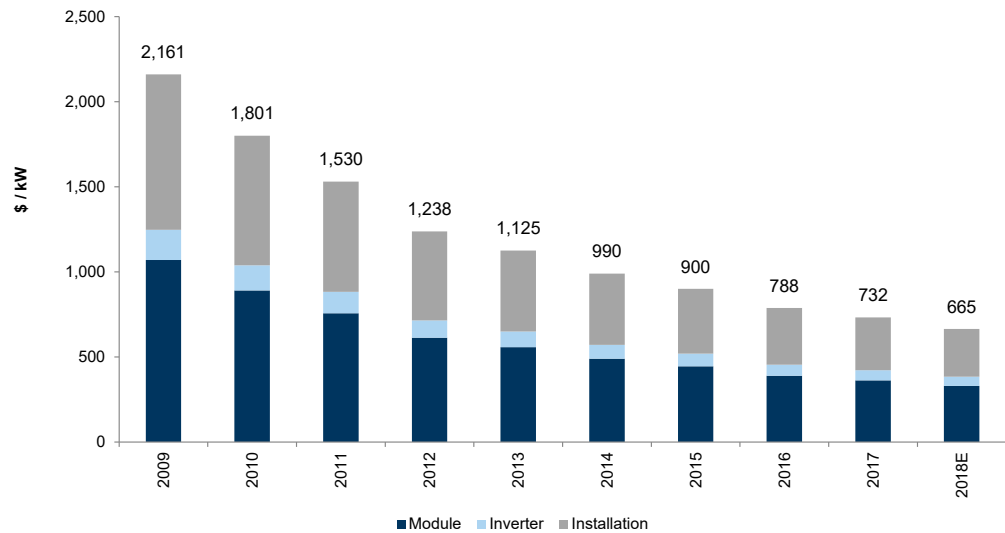


Source: Goldman Sachs Global Investment Research, IRENA

1) Lower module and installation expenses behind the 70% reduction in costs vs 2009

Exhibit 21 details the key drivers behind the c.70% investment cost reduction for utility-scale solar PV projects since 2009. Module prices and installation costs have on average accounted for 49% and 42% of the absolute cost reduction (in US\$/kW) over that period.

Exhibit 21: Solar investment costs have fallen c.70% vs 2009 on lower module and installation costs
Global investment cost (US\$/kW) for utility-scale solar PV projects (GSe based on company and IRENA data)

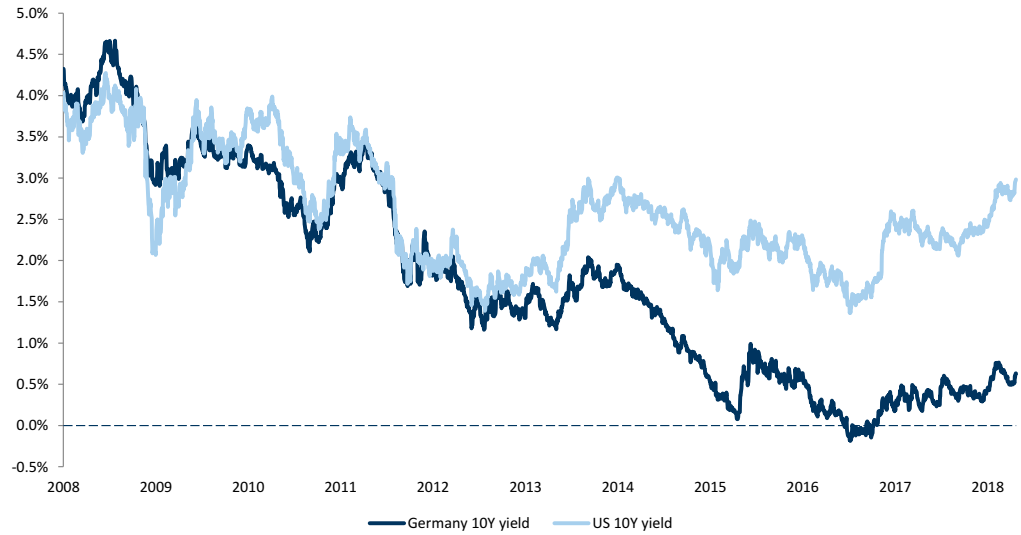


Source: Goldman Sachs Global Investment Research, Company data, IRENA

2) Cheap financing has significantly improved the economics of solar projects

Over the last 10 years, financing costs (and the corresponding required return threshold) for solar PV projects have come down significantly, mostly owing to macro conditions (Exhibit 22).

Exhibit 22: Financing costs hit a low in 2016/17, with only a muted increase in Europe since then
 10Y government bond yields in Germany and US since 2008

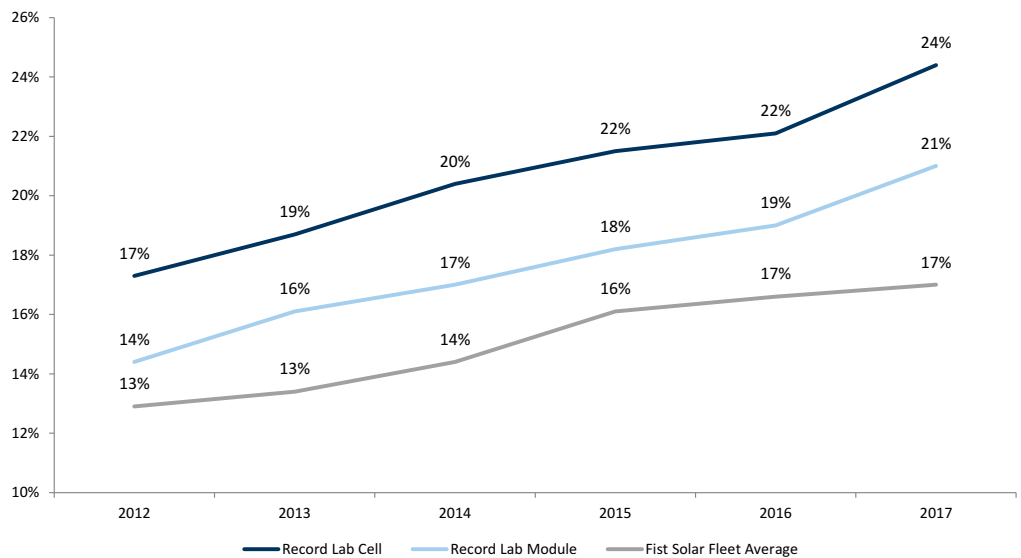


Source: Datastream

3) Panel efficiency has improved >30% in recent years

Since 2012, technological improvements have led to efficiency improvements ranging between 50% (for lab modules) and 30% (for commercially available panels).

Exhibit 23: Module efficiency has significantly improved over the past five years
 Solar PV module efficiency



Source: First Solar, IRENA

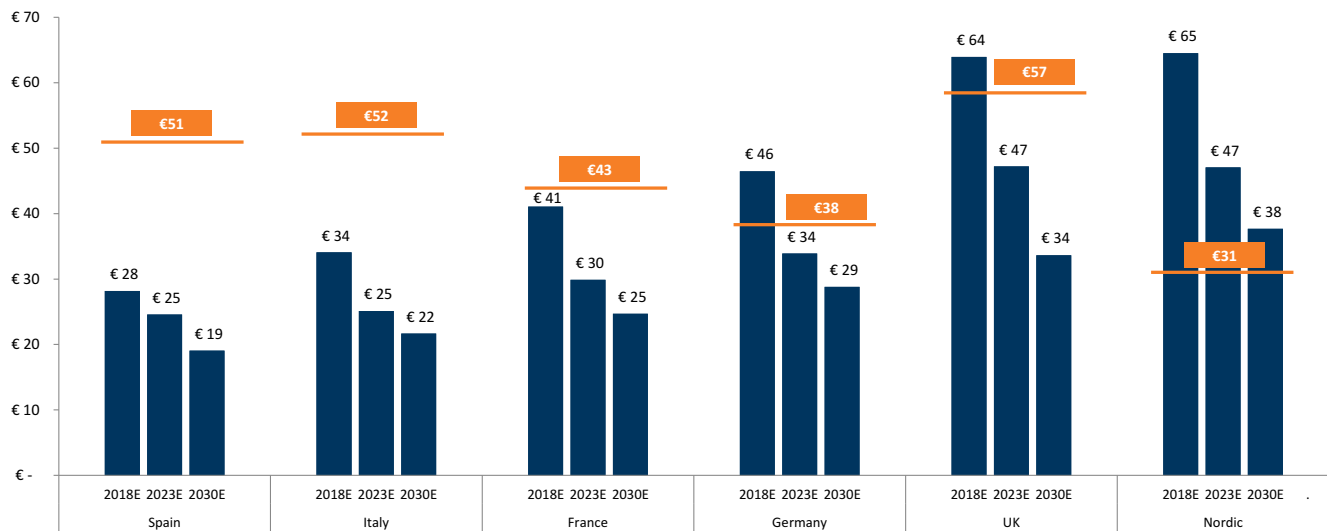
Solar LCOE could fall by 30%-50% by 2030

Lower capital costs, lower opex and better modules efficiency is likely to imply ongoing cost reductions in solar PV, despite rising cost of capital. We estimate that LCOE could fall by 10%-25% until 2023 – depending on the region – and by 30%-50% to 2030.

Regional Solar LCOE forecasts: Meaningful reductions yet to come

We model solar LCOEs across major European markets and estimate 10%-25% reduction by 2023 and 30%-50% by 2030. By 2023, we see solar PV well below forward curves in all regions but Nordics, with LCOE ranging from €25/MWh (Spain, Italy) to €47/MWh in the UK. By 2030, we see solar prices at around €20/MWh in Southern Europe, at €25-30/MWh in France and Germany, in the mid-€30s in the UK and high-€30s in the Nordic region.

Exhibit 24: The spread between LCOEs and forwards suggests that Spain and Italy will be at the forefront of the rise in solar
Solar PV LCOEs vs 2019 forward prices in orange (€/MWh)



Source: Goldman Sachs Global Investment Research, Bloomberg

Our framework to establish solar PV take-up by country

We observe that the potential for solar PV development in Europe's main power markets is driven by five key metrics:

- 1. Irradiation levels.** The intensity and frequency of sunshine determines how much sunlight is converted into electricity. We look at load factors - a proxy for irradiation.
- 2. Regional power prices.** Higher power prices imply a better opportunity cost for merchant renewables. Industrial clients could be lured into long-term offtakes, owing to an attractive discount versus wholesale prices.
- 3. Presence of spare/backup capacity.** Solar output is variable throughout the day; the presence of backup generation is necessary to satisfy demand in hours of darkness.

4. **Grid status.** The variability and distributed nature of solar requires a flexible grid to balance loads and offset supply shortages. Given the strong regional bias of solar, we see the rising need for investments in transmission as well as in distribution. Our ranking goes from green (modern grid) to red (significant bottlenecks).
5. **Energy policy.** Solar is most likely to expand in countries with energy policy favourable to renewables. Policy could be a strong driver to develop solar, for instance by enabling a better grid infrastructure and proper backups (gas, hydro, batteries).

Based on this framework, Spain would appear the early mover (visible impact by 2023-25); Italy could be second (2025-27); while France and the UK would see threats during 2027-30 (Germany post-2030, owing to large-scale closures in legacy capacity and a lower starting point for power prices). We see no threat in the Nordic region, as currently c.90% of supply is already from fixed-cost, must-run power generation facilities, irradiation levels are lower and as power prices are already the lowest in Europe.

Exhibit 25: Spain and Italy rank highly thanks to favourable irradiation and high power prices

Major European power markets compared on key metrics for solar PV development

	Irradiation Levels	Wholesale Power Price	Grid Status		Shutdowns by 2030	Policy
	(Load Factors, 2023E)	(2019 €/MWh)	Transmission	Distribution	(GW)	
Spain	20%	51			18	Supportive
Italy	18%	53			7	Uncertain
France	15%	43			13	Less supportive
Germany	13%	38			42	Supportive
UK	12%	57			11	Less supportive
Nordic	9%	31			5	NM

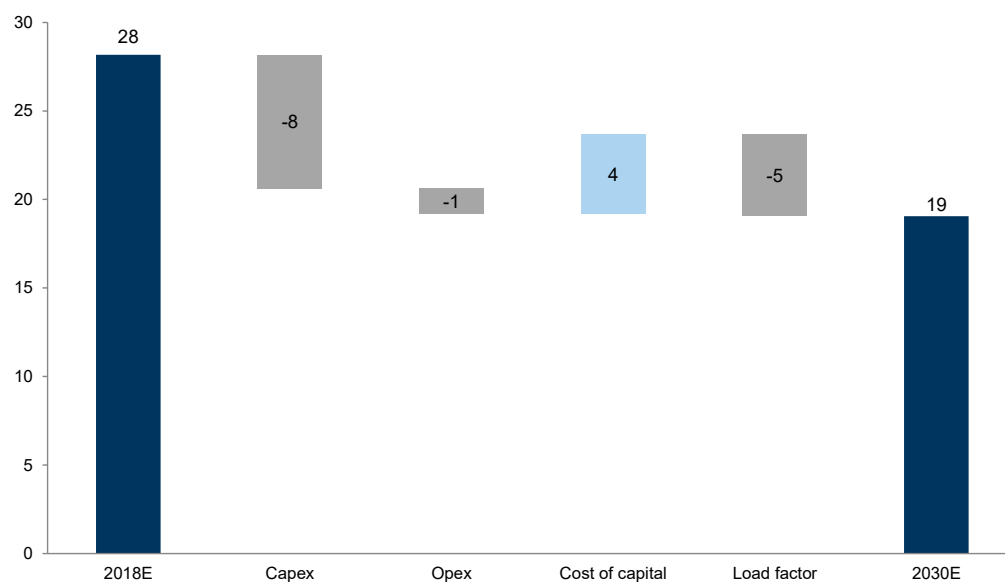
Source: Goldman Sachs Global Investment Research

Dissecting the reduction in solar LCOE

As explained earlier, we expect the reduction in Solar PV LCOE to come from lower costs/kW, higher efficiency (load factors) and an improvement in opex. This would outweigh the increase in cost of capital that we assume (+150 bp). Exhibit 26 shows the example for Spain, where we expect a c.30% reduction in costs per MWh.

Exhibit 26: We expect LCOE to fall mainly driven by lower capex and higher load factors

Solar LCOE drivers 2018-2030 (Spain, €/MWh)



Source: Goldman Sachs Global Investment Research

Our assumptions

Exhibit 29 summarises our main assumptions. Namely: (i) a 5% annual reduction in equipment costs until 2025, and a 2% reduction thereafter; (ii) 200-400 bp improvements in load factors across Europe to 2030; (iii) a marginal reduction in opex, and (iv) a 150 bp increase in cost of capital.

Exhibit 27: Key assumptions for our European solar LCOE model

Cost assumptions	2018	2023	2030	2018-30 CAGR
Capex Continental Europe (\$/kW)	665	499	433	-3.5%
Capex UK (\$/kW)	802	601	420	-5.2%
Opex Continental Europe (\$/kW)	12.0	11.7	10.9	-0.8%
Opex Nordics (\$/kW)	12.6	12.3	11.5	-0.8%
Opex UK (\$/kW)	15.0	14.6	13.6	-0.8%
Load factors	2018	2023	2030	2018-30 CAGR
Germany	13%	14%	16%	1.75%
Spain	20%	21%	24%	1.50%
Italy	18%	19%	21%	1.50%
France	15%	16%	18%	1.75%
UK	12%	12%	14%	1.50%
Nordics	9%	10%	12%	1.75%

Source: Goldman Sachs Global Investment Research

Corporate PPAs likely to accelerate the process

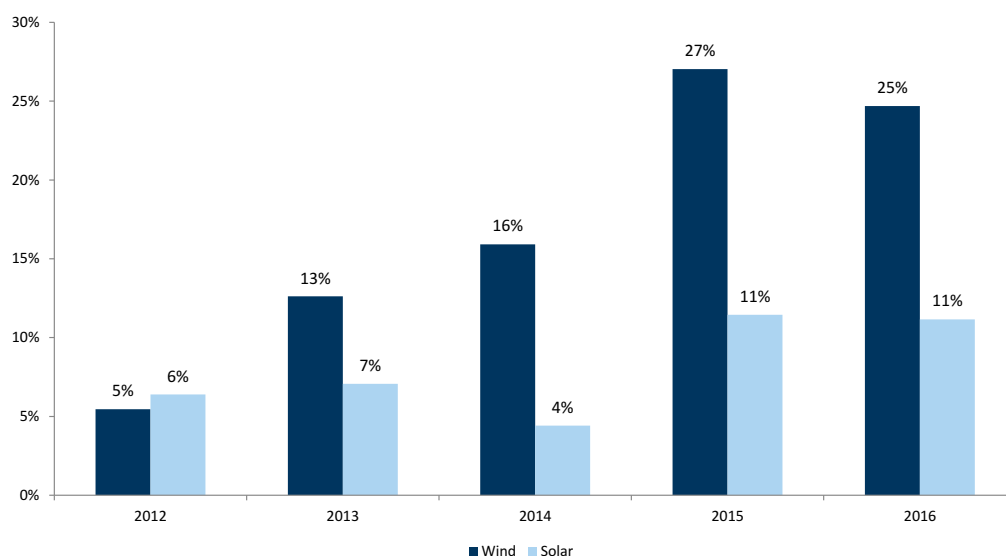
Similar to what has been happening in the US, European corporates have started to sign long-term power offtakes from renewable sources; most of these contracts have been signed in Spain and the Netherlands. We believe this new tool might accelerate the development of solar PV, and is one of the reasons behind the 24 GW of PV projects currently under development in the country which, coupled with 20 GW of wind projects, imply a c.45% increase in the total generation fleet.

In the US, corporate PPAs already play a major role

As shown in Exhibit 28 below, in the US corporate PPAs play an increasingly important role in driving renewable installations (across both wind and solar) as federal subsidies such as ITCs and PTCs are phased out.

Exhibit 28: Corporate PPAs are an increasingly important driver of US renewable installations

Corporate PPAs as a % of total renewables installations in the following year (x-axis corresponds to year of PPA origination)

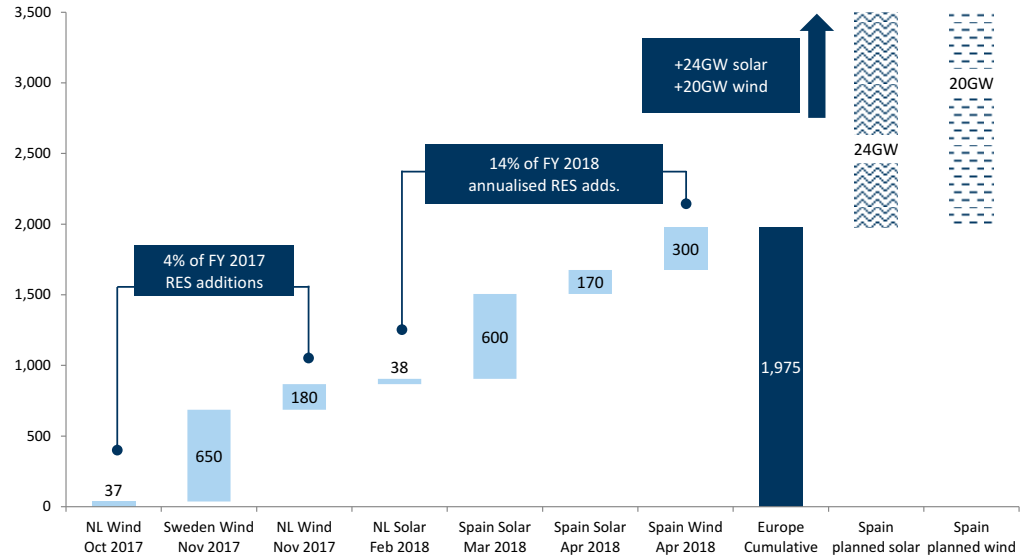


Source: Goldman Sachs Global Investment Research, IRENA

Europe has just turned to C-PPA

Similar to what has been happening in the US, European corporates have started to sign long-term power offtakes from renewable sources; most of these contracts have been signed in Spain and the Netherlands. Year-to-date, about 10% of renewables (RES) additions have come under corporate PPAs. We believe this new tool might accelerate the development of solar PV: it is one of the reasons behind the RES projects (24 GW of solar and 20 GW of wind) currently under development in Spain.

Exhibit 29: Since 2017, the corporate PPA market has been picking up pace in Europe
Major PPA contracts signed in Europe over the last two years (MW)

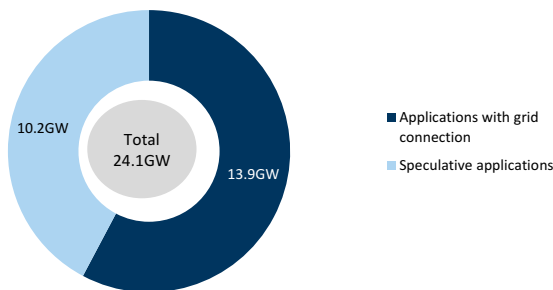


Source: Goldman Sachs Global Investment Research, IRENA

Spain is spearheading C-PPA

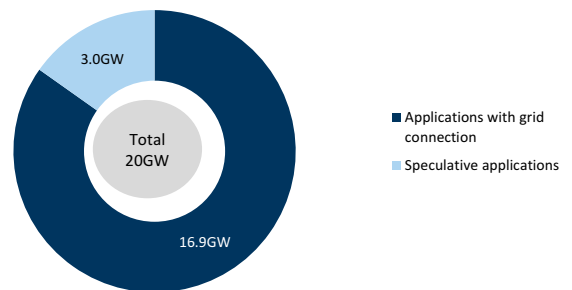
Data by the system operator Red Electrica (REE) shows c.45 GW of combined requests (24 GW from solar PV, 20 GW from wind) to develop renewables. Although some relate to the 2017 auctions (>8 GW), the bulk seems to be following a “merchant logic”. In line with recent agreements, RES developers are seeing the opportunity of signing long-term offtakes with industrial players (corporate PPAs, or C-PPA). This would allow corporates to set a fixed price for electricity for up to 15 years. Considering that currently solar PV is c.45% cheaper than the forward curves, and as we expect the gap to widen in the coming 3-5 years, we expect this process to accelerate.

Exhibit 30: Spain currently has a 24GW “subsidy-free” solar PV pipeline, of which 14GW with grid connection already granted
Planning applications for “subsidy-free” solar PV projects in Spain



Source: Goldman Sachs Global Investment Research, REE

Exhibit 31: Spain has a 20GW onshore wind pipeline - sufficient to double the country’s current installed capacity
Planning applications for “subsidy-free” onshore wind projects in Spain



Source: Goldman Sachs Global Investment Research, REE

EU 2030 targets have upside risk

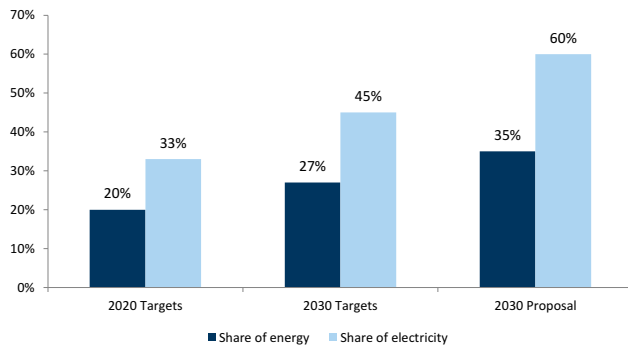
The European Parliament has suggested raising the 2030 renewable energy target from 27% to 35%, motivated by improved economics. Considering some pushbacks by the Council, we assume that the final outcome might settle at 30%-32%, based on similar EU decisions. Since the current target implies a 45% share for renewable electricity generation by 2030, we estimate that under a revised 35% target, the share of renewable electricity would need to increase to 60% - or nearly double vs the current EU-28 average of c.30%.

Europe: 2020 and 2030 targets suggest ongoing RES additions

Europe currently generates about 30% of its power from renewables (including hydro) and plans to raise this to at least 45% by 2030. Although 2020 RES targets are in reach, objectives for 2030 do require continued investments in solar and wind.

Exhibit 32: Europe plans to reach 45% output from RES from c.30% today

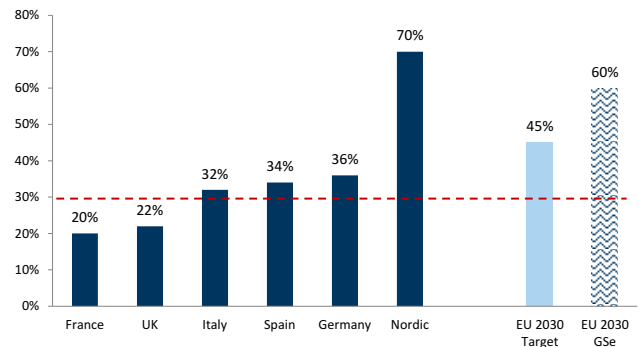
EU targets for renewable energy as a % of total energy consumption and electricity production



Source: European Commission

Exhibit 33: EU 2030 targets imply significant upside to Europe's demand for renewables

Renewable penetration as % of total electricity generation (2017) vs 2030 EU target and EP proposal

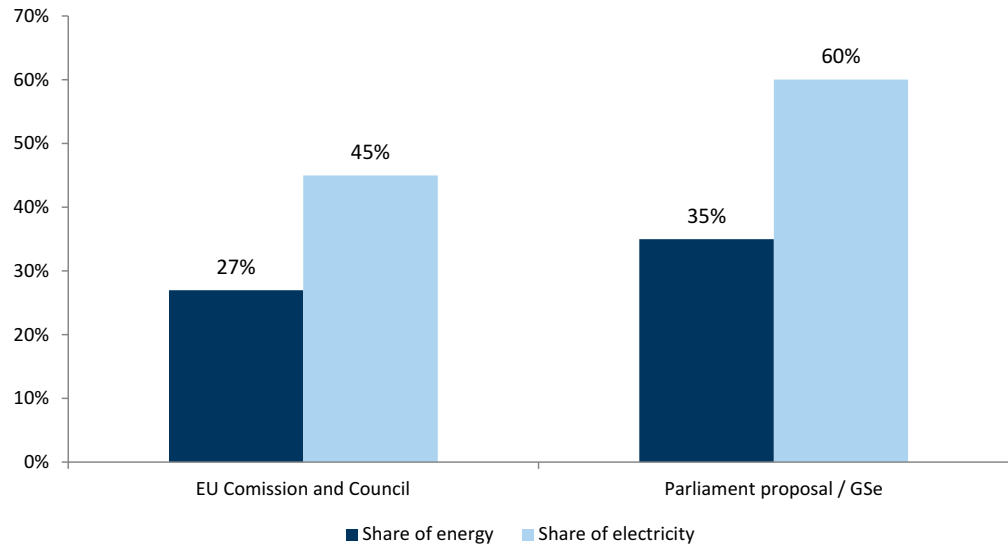


Source: Eurostat, European Commission, Goldman Sachs Global Investment Research

We see upside risk to EU 2030 targets

The European Parliament (EP) has proposed increasing the binding EU 2030 renewables target from "at least 27%" to 35%. The EP argues it would be cost-effective given improved renewables economics. However, according to Platts, the European Council is so far sticking to the 27% target proposed by the Commission at the end of 2016.

Exhibit 34: European Parliament has proposed a 35% target vs 27% backed by Commission and Council
2030 renewable targets/views

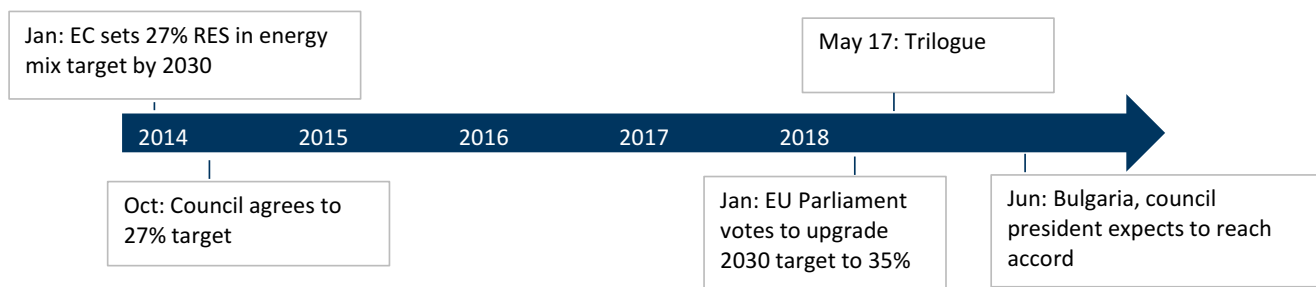


Source: Platts, Goldman Sachs Global Investment Research

Informal discussions are due on May 17. Bulgaria, the country leading the negotiations, has expressed interest in reaching an agreement by the end of June (Platts, April 23, 2018). Once an informal agreement is reached, the EP will hold a vote. If the text goes through, the council can adopt the new legislation, while further changes would trigger another round of negotiations followed by a second vote and formal adoption by the council.

Exhibit 35: 2018 may see the EU's 2030 renewable targets being upgraded to 35% (vs 27% currently)

Timeline of key events related to the potential increase of EU renewables targets



Source: Goldman Sachs Global Investment Research, European Commission, EU Council

Earnings risk of 15%-40% for the most exposed names

We estimate that, by 2030, legacy generation profits (less than 15% for the entire sector, but c.15%-55% of EBITDA for the most exposed names) could face a c.30% reduction, equivalent to an EPS squeeze of 15%-40% for the most exposed names. Such a scenario would likely trigger a major response by the industry, including: (i) consolidation, to gain more exposure to RES, (ii) portfolio reorganisations, to lower exposure to legacy assets, and (iii) step up in RES capex, to offset the earnings cliff.

Only c.15% of EBITDA from legacy generation, but very concentrated

Following the decline in commodity prices since mid-2008, subdued growth in power demand and the rise in renewables' market share, the EBITDA from (merchant, ie unregulated) power generation activities in Europe now "only" accounts for c.15% of sector EBITDA, vs >40% in 2010. This is equivalent to c.€15 bn, based on our 2020 estimates.

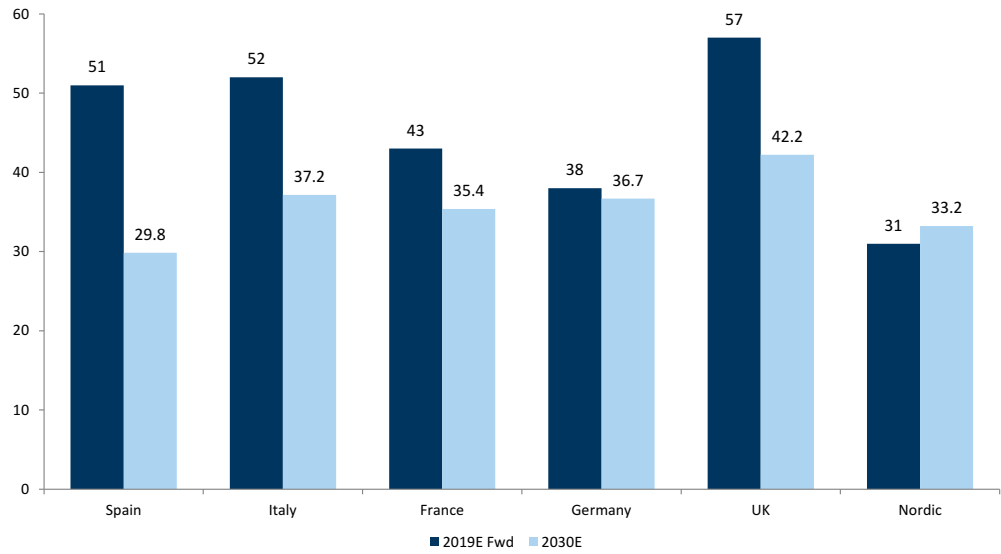
About 30% of legacy generation at risk from solar and RES

We estimate that, by 2030, legacy generation profits could face a c.30% reduction, owing to lower power prices and the full phase-out of coal (and lignite) plants.

To estimate this, we have made the following assumptions:

- **Hydro and Nuclear profits** drop in line with the reduction in power prices that we estimate: by 2030 we expect power prices to be set as a combination of gas plants and must-run technologies (solar, wind, nuclear mostly). We estimate power prices by observing the hourly output by technology; this allows us to capture the seasonal/daily behaviour of renewable sources and of demand.
- **Coal plants** fully phased out by 2030, owing to their lack of competitiveness.

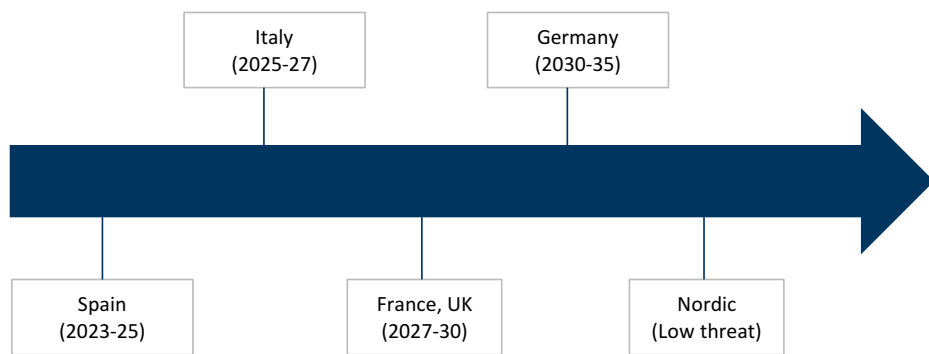
Exhibit 36: Downside risk to power prices in most of Europe, owing to the rise in solar (and wind)
 2019E forward curves vs our 2030 power price forecast (£/MWh)



Source: Goldman Sachs Global Investment Research, Bloomberg

As mentioned earlier, and as we detail in the next chapter, Spanish Utilities face the largest threat, in our view. They could see earnings impacted on a 5-year basis, and could de-rate before the rest of the peer group.

Exhibit 37: Biggest threat in Spain, then Italy, then the rest...Nordic should be more insulated
 Timeline of earnings risk from the rise of solar



Source: Goldman Sachs Global Investment Research

Assumptions

- **Energy mix:** we assume that renewables will reach 50%-60% in the power generation mix, depending on the country.
- **Coal and Lignite phaseout:** by 2030, we assume that all coal and lignite plants will be phased out.
- **Nuclear partial phaseout:** reaching 50%-60% of output from renewables would lead to “renewables oversupply” in certain hours (eg, solar during daytime summer weekends) and to a “renewable shortage” some other times (eg daytime winter during weekdays). This means that the non-renewable capacity in the system would increasingly have to be flexible (eg gas plants). In this design for power systems, the role of nuclear would be more marginalized. We assume a partial phaseout in France and the UK, and suggest that Spain might follow a similar route (not in our base case though).
- **Power prices:** to estimate the 2030 end-game, we estimate: (i) 2%-5% annual decline in solar equipment costs, (ii) slight reduction in opex/kW, and (iii) 250-400 bp improvement in load factors (module efficiency). On this basis, power prices are set to decline in most regions (Nordic is the exception), with Spain and Italy showing the largest threats.
- **Power demand:** we assume 0.50%-0.75% annual increase in demand to reflect the rising electrification of the economies, despite the negatives from demand side management.

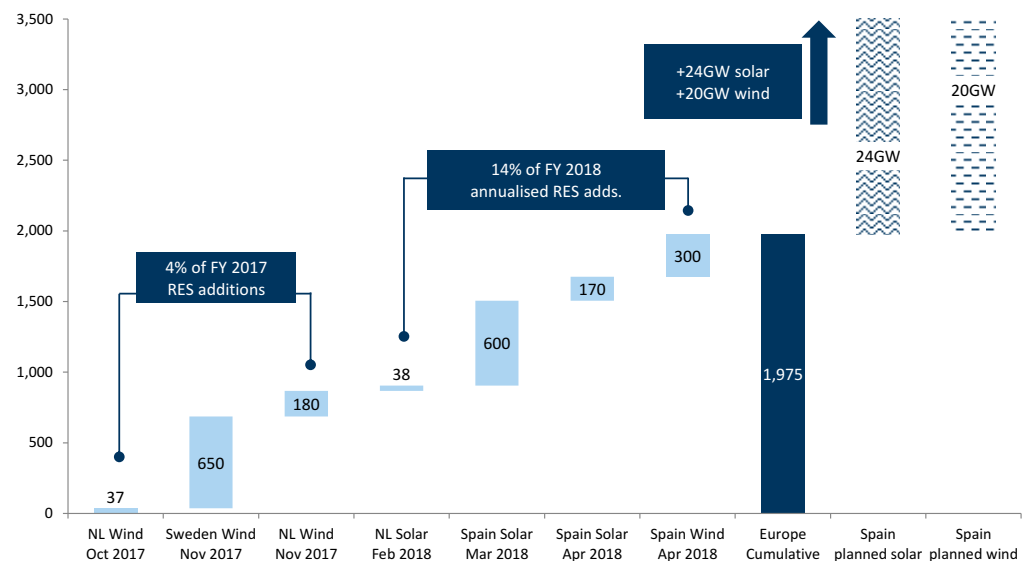
Spain the early “solar mover”

When estimating how soon a country may be impacted, we observe: i) irradiation levels, ii) regional power prices, iii) presence of spare/backup capacity, iv) grid bottlenecks, v) energy policy. Based on this framework, Spain would appear the early mover (visible impact by 2023); Italy could be second (2025-27); France and UK would see threats during 2027-30; while Germany is likely to feel an impact only post 2030 owing to large-scale closures in legacy capacity (nuclear, coal & lignite) and a lower starting point for power prices. We see no threat in the Nordic region, as currently c.90% of the supply is already from fixed-cost, must-run power generation facilities.

Spain is leading on corporate PPAs: 24 GW requests for Solar PV

As explained earlier, Spain has been a leading force in fostering a corporate PPA market for solar (Exhibit 38). Year to date, we have seen over 1GW of C-PPAs signed in Spain alone, equivalent to roughly 14% of the expected renewable additions this year and roughly 50% of the total large-scale C-PPA volumes signed in Europe so far.

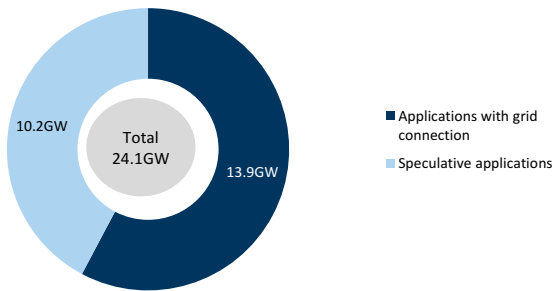
Exhibit 38: We believe 2018 could be a turning point for corporate PPAs in Europe
Major corporate PPA contracts signed in Europe since 2017 (MW)



Source: Company data, Goldman Sachs Global Investment Research

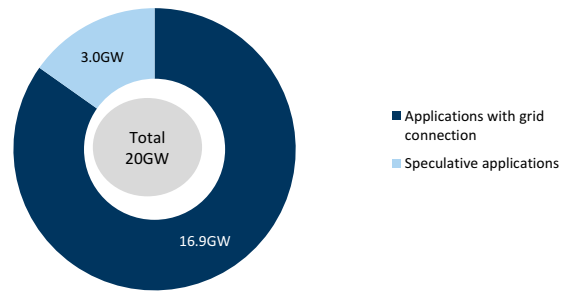
Attractive economics and the ability to sign corporate offtakes have led to requests to develop 24 GW of solar PV, based on data by the system operator REE. This is equivalent to c.20% of the total installed base across all technologies, and nearly 4x the installed solar PV capacity. Similarly, Spain has demands for 20GW of wind which, if fully commissioned, could double the country’s onshore wind capacity.

Exhibit 39: Spain currently has a 24GW “subsidy-free” solar PV pipeline, of which 14GW with grid connection already granted
 Planning applications for “subsidy-free” solar PV projects in Spain



Source: Goldman Sachs Global Investment Research, REE

Exhibit 40: Spain has a 20GW onshore wind pipeline - sufficient to double the country’s current installed capacity
 Planning applications for “subsidy-free” onshore wind projects in Spain

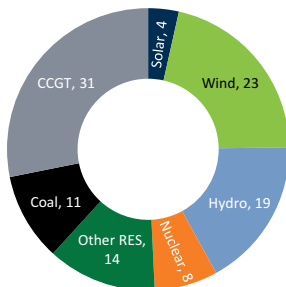


Source: Goldman Sachs Global Investment Research, REE

Government targets may increase solar PV ten-fold

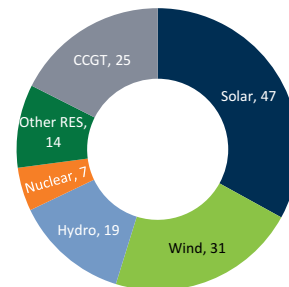
According to a panel of experts advising the Spanish government, Spain could achieve 47GW of solar capacity (nearly 10x today’s capacity) and 31GW of wind (+35%). In our view, this would imply a significant shift in the country’s generation mix towards two-thirds of the capacity being renewable.

Exhibit 41: Spain’s current power generation mix (GW)



Source: Goldman Sachs Global Investment Research, REE

Exhibit 42: Spain’s potential power generation mix in 2030 (GW)



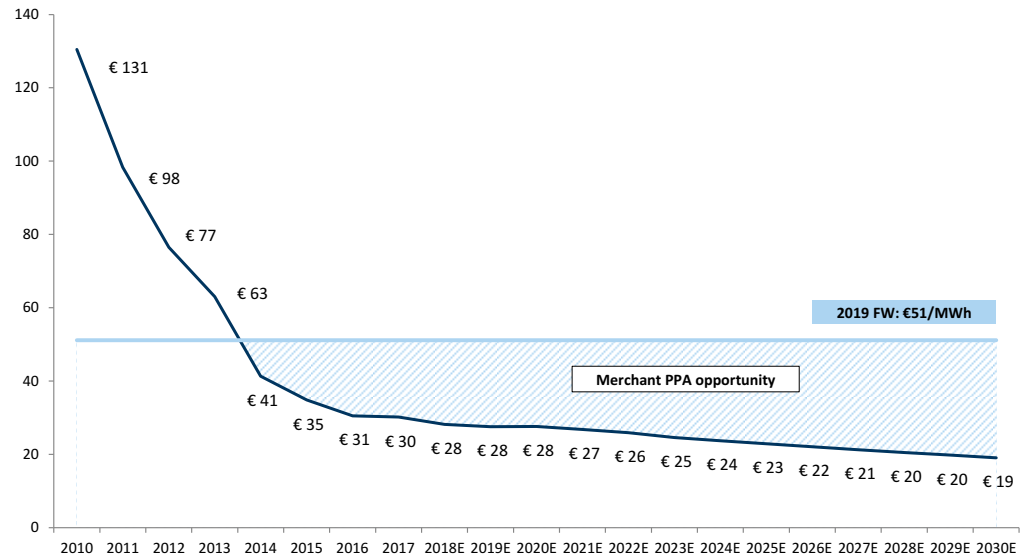
Source: Goldman Sachs Global Investment Research, REE, Spanish Expert Commission on Energy Transition

Spanish Solar LCOE at €25/MWh by 2023 and sub-€20/MWh by 2030

Attractive load factors (20%-21% in the central/southern regions (Andalucia, Castilla-La Mancha, Extremadura) and the ongoing reduction in equipment/installation costs have allowed for a c.80% reduction in large-scale solar PV LCOE since 2010. For 2018, we estimate that solar PV could be at a c.45% discount to merchant curves, as seen in the following exhibit. We estimate that solar costs will keep dropping to less than €20/MWh by 2030.

Exhibit 43: Spain's solar LCOE (c.50% below forwards now and declining) implies significant potential for merchant solar

Spain: Solar PV LCOE vs 2019 power forward



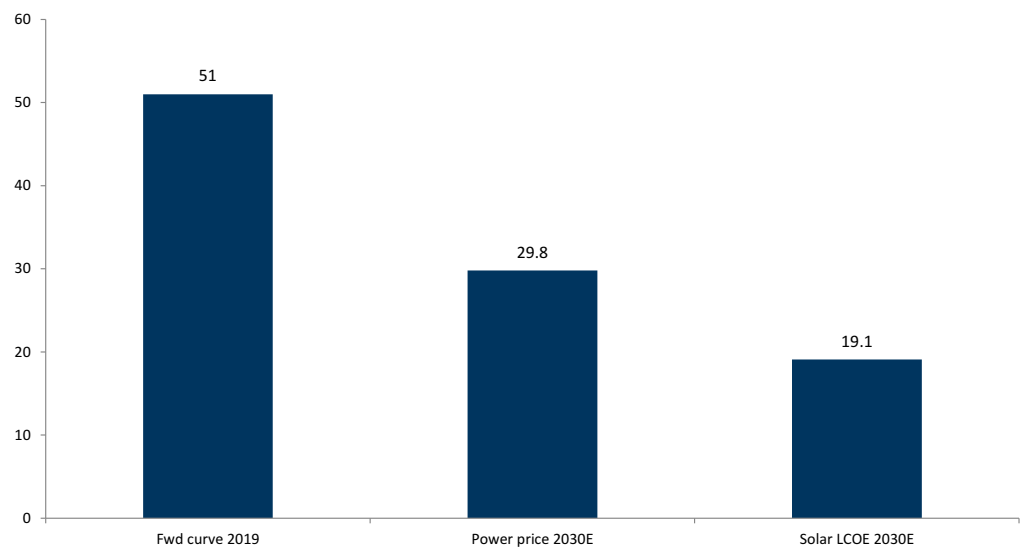
Source: Goldman Sachs Global Investment Research, Bloomberg, IRENA

Modelling Spanish power prices: >40% downside risk

On our estimates, by 2030, Spanish power prices could fall by over 40%, to just below €30/MWh. By then, we estimate that the solar PV levelised cost of energy would be less than €20/MWh.

Exhibit 44: Spanish power prices could decline over 40% by 2030

Spain: 2019 forward curve vs 2030 forecast vs 2030 Solar PV LCOE (€/MWh)



Source: Goldman Sachs Global Investment Research, Bloomberg

Estimating supply/demand by 2030: The “experts’ report”

Exhibit 45 shows the dramatic change expected in the Spanish energy mix. The right hand column represents the capacity mix recommendation from the commission of experts, appointed by the Spanish government. There, we note the 10-fold increase in solar PV capacity expected, from less than 4 GW to nearly 50 GW. By 2030, solar PV could account for about one-third of the Spanish installed base. Adding wind and other RES, renewables could represent >75% of the total.

Exhibit 45: Spain: Renewables could be >75% of the installed base by 2030

Spain 2018 vs 2030 capacity (MW)

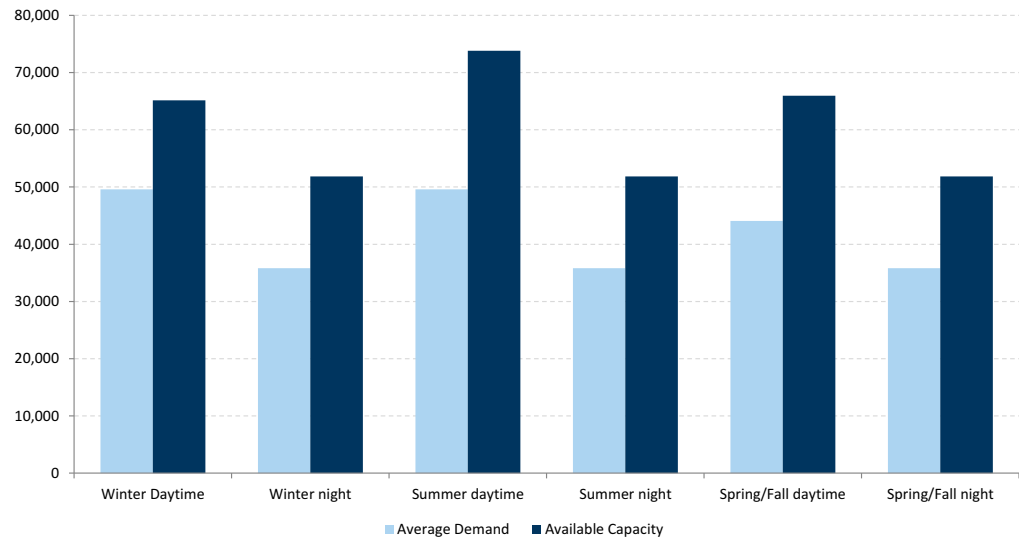
Technology	2018E	2030E	Change
Hydro	18,669	18,669	0
Nuclear	7,866	7,117	-749
Wind	23,053	31,000	7,947
Solar	3,800	47,000	43,200
Other RES	13,572	13,572	0
Lignite	0	0	0
Coal	10,908	0	-10,908
Gas	30,517	25,000	-5,517
Other	0	0	0
Total	108,385	142,358	33,973

Source: Goldman Sachs Global Investment Research, Spanish Committee of Experts on Energy Transition (Comision de Expertos sobre transicion energetica)

Seasonality becomes a critical issue

Understanding seasonality will become a key issue to forecast power prices. By 2030, we envisage a system that – if still fully merchant – would be characterised by a substantial increase in price squeezes (think about summer weekends, characterised by low demand and high solar production) and by less frequent price spikes. Exhibit 46 shows the persistent excess of available capacity vs demand, by season (daytime + night), on our forecasts.

Exhibit 46: Spain to remain oversupplied in all seasons
 Spain: 2030E available capacity vs average demand (MW)



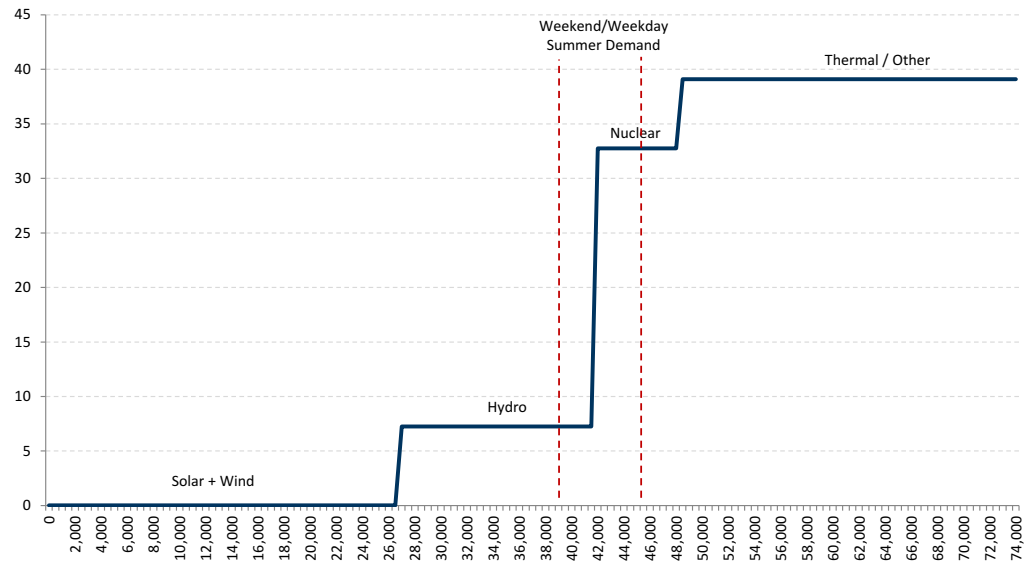
Source: Goldman Sachs Global Investment Research

The increasingly marginalised role of thermal and nuclear

Summer days will become particularly interesting, as the average demand (38-45 GW) would imply (i) no production from thermal in a typical day, and (ii) excess nuclear output. On the latter point, our analysis shows that Spanish nuclear by 2030 would run less than 60% of the time (moments of limited demand and decent hydro availability - eg March or October - would also lead to excess nuclear output). Considering the limited flexibility of this technology, we suspect that – under such a capacity scenario – nuclear facilities could be partly phased out by then.

Exhibit 47: Spanish supply curve shows that thermal would no longer be needed by 2030 during summer daytime

Spain supply curve 2030E (variable costs in €/MWh on Y-axis, MW on X-axis)

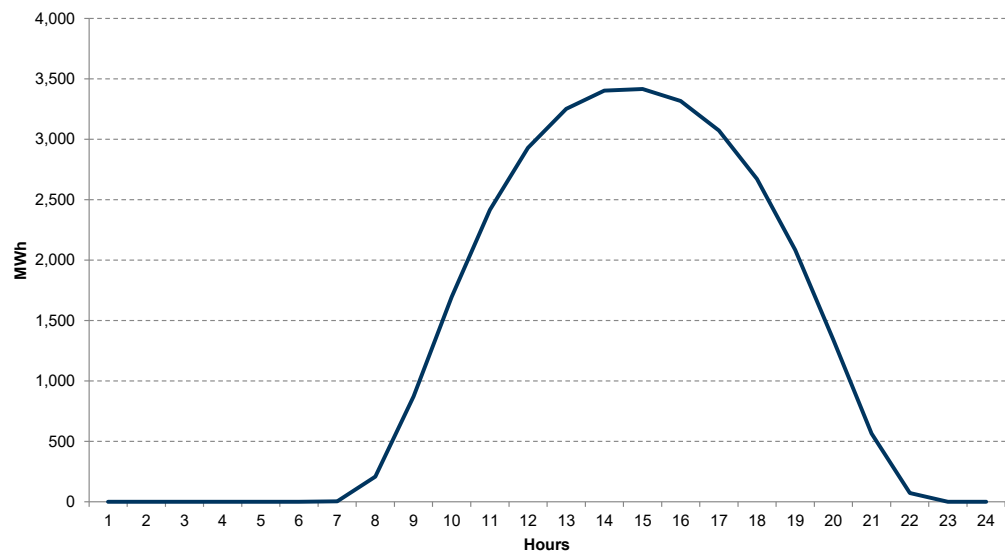


Source: Goldman Sachs Global Investment Research

Clearly this chart is based on average summer days (daytime). If we were to focus on particular windy and sunny days, at 12-17 o' clock, we could see that wind, solar and hydro would entirely satisfy demand.

Exhibit 48: Solar PV during daytime is quite reliable

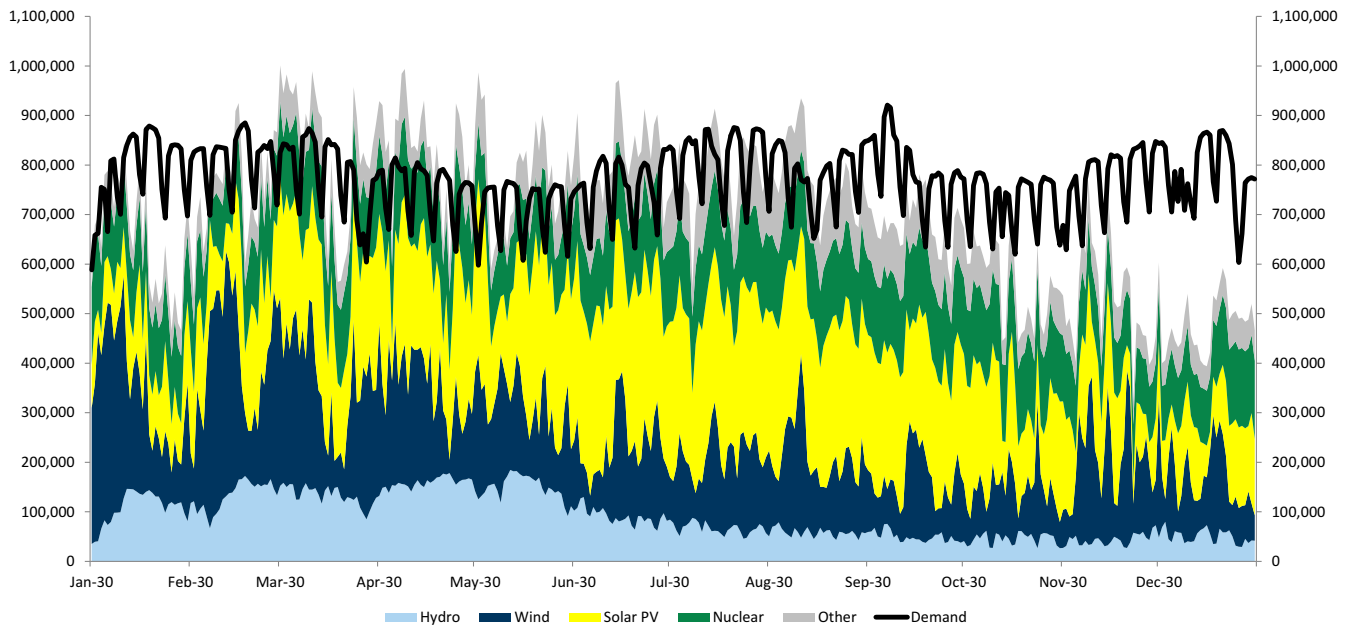
Maximum daily production of Solar during July 2016 (Spain)



Source: Goldman Sachs Global Investment Research, REE

Our simulation for 2030 suggests that the impact on supply/demand from a rise in RES penetration is likely to be game-changing. As seen in Exhibit 49, we estimate that about 57% of the time, must-run technologies (hydro, wind, solar, nuclear, other renewables) would fully meet or exceed demand. During those hours, we would expect very low prices. Our seasonal daytime/night analysis would show a worse picture during moments of particularly low demand, such as weekends.

Exhibit 49: Moving to 60% capacity from renewables would make the market “long” c.57% of the time
 Daily generation from “must run” technology and demand, 2030E (GWh)



Source: REE, Goldman Sachs Global Investment Research

Other European countries to follow, with a lag

Exhibit 50 summarises the analytical framework we use to estimate the take-up potential for solar PV across the main European power markets. We note that Italy shares many of Spain’s features and should therefore follow a similar path. The rest of the countries would see an impact beyond 2025 (France, UK), beyond 2030 (Germany), or not at all (Nordic).

Exhibit 50: Spain and Italy appear to have the best potential for a prolonged boom in Solar PV
GS framework to assess take-up of Solar PV

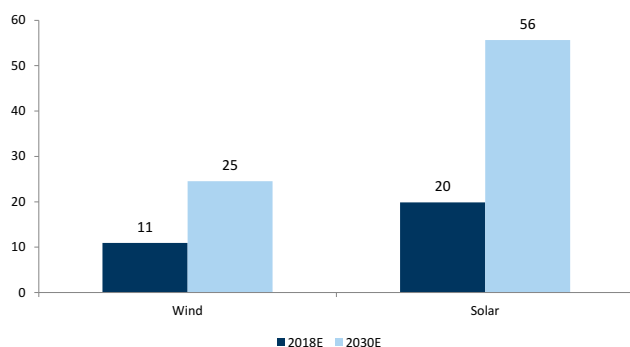
	Irradiation Levels	Wholesale Power Price (2019 €/MWh)	Grid Status		Shutdowns by 2030 (GW)	Policy
	(Load Factors, 2023E)		Transmission	Distribution		
Spain	20%	51	●	●	18	Supportive
Italy	18%	53	●	●	7	Uncertain
France	15%	43	●	●	13	Less supportive
Germany	13%	38	●	●	42	Supportive
UK	12%	57	●	●	11	Less supportive
Nordic	9%	31	●	●	5	NM

Source: Goldman Sachs Global Investment Research

Italy: Next in line

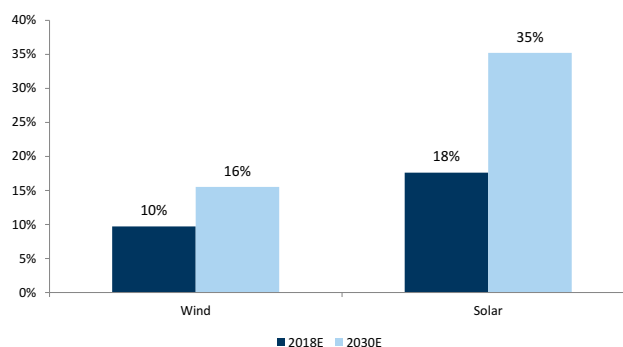
Italy shares many of the features we found in Spain, such as high irradiation levels, high power prices, a modern power grid, limited shutdowns by 2030 and a policy generally favourable to renewables. In our modelling, we estimate that Italy will reach 25 GW of wind and 56 GW of renewables by 2030.

Exhibit 51: Italian solar growth to pick up
Italy wind and solar capacity, GW



Source: Goldman Sachs Global Investment Research

Exhibit 52: Solar to account for 35% of capacity by 2030E
Italy share of wind and solar as a percentage of total capacity

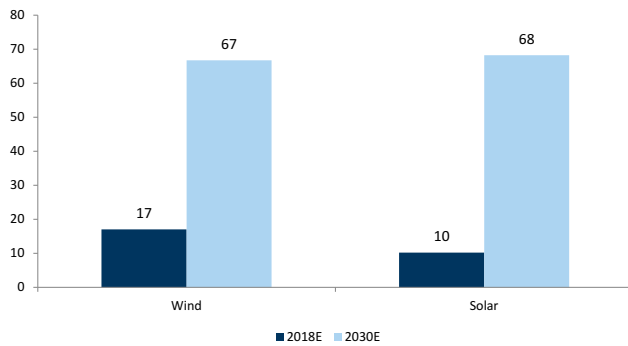


Source: Goldman Sachs Global Investment Research

France and UK: Impact in 2027-30

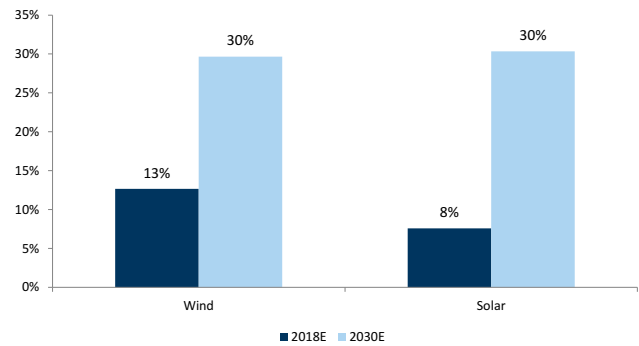
Although France has regions with good irradiation potential, power prices aren't as high as in Spain or Italy and the government may not be as supportive of such a fast renewable development, to avoid major nuclear disruptions.

Exhibit 53: RES growth more balanced in France
France wind and solar capacity, GW



Source: Goldman Sachs Global Investment Research

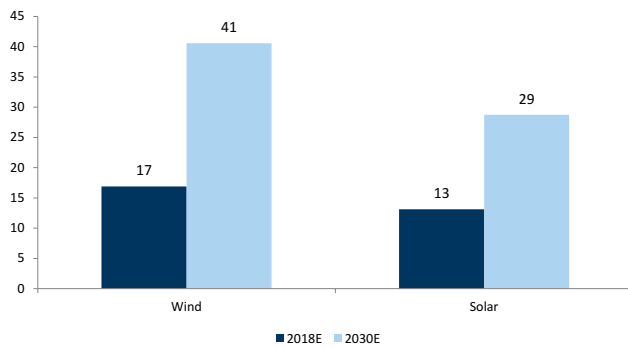
Exhibit 54: Wind and solar to account for 60% of capacity by 2030E
France share of wind and solar as a percentage of total capacity



Source: Goldman Sachs Global Investment Research

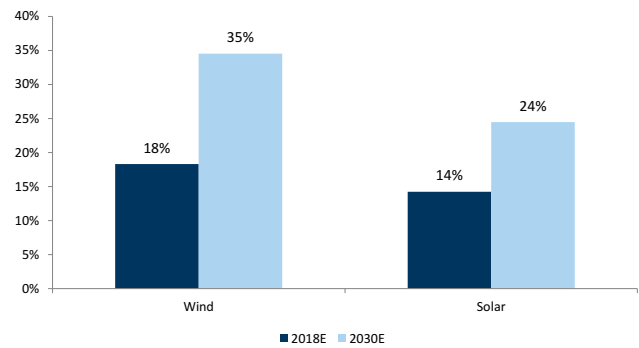
In the UK, poor irradiation and limited government support would imply that the impact should be more muted.

Exhibit 55: Solar deployment capped by poor irradiation
UK wind and solar capacity, GW



Source: Goldman Sachs Global Investment Research

Exhibit 56: Solar to lag wind and represent c.25% of installed capacity
UK share of wind and solar as a percentage of total capacity

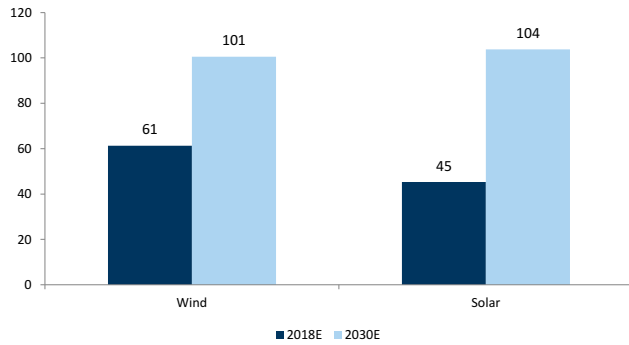


Source: Goldman Sachs Global Investment Research

Germany: Impact post-2030

Although Germany has been a prime promoter of renewable sources, we estimate that nuclear, coal and lignite phaseout would remove nearly two-thirds of the current supply from the mix. This is why, despite a major step up in RES, we don't envisage a major decline in prices. Actually, we estimate that Germany would not have enough back-up capacity and would have to support the development of up to 30 GW of gas plants.

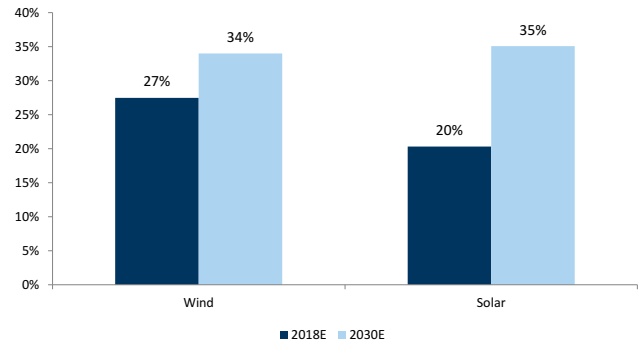
Exhibit 57: German deployment of renewables to continue
Germany wind and solar capacity, GW



Source: Goldman Sachs Global Investment Research

Exhibit 58: Solar and wind to account for nearly 70% of installed capacity by 2030E

Germany share of wind and solar as a percentage of total capacity

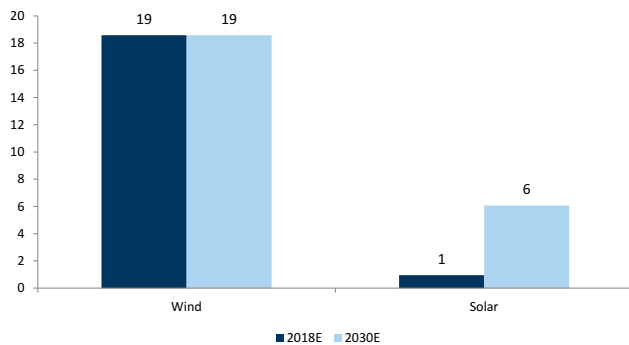


Source: Goldman Sachs Global Investment Research

Nordic: Insulated from the solar threat

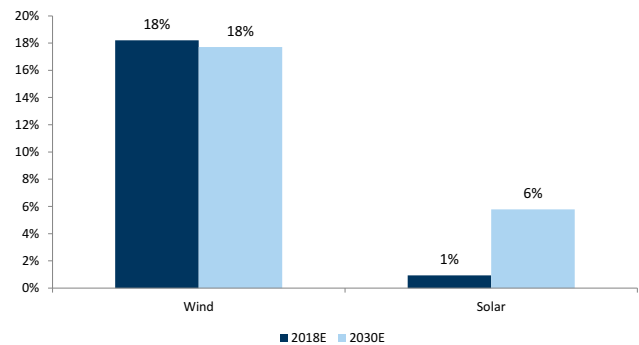
In the Nordic region, about 90% of production already comes from must-run technologies (hydro, nuclear, wind). Although we envisage the ongoing addition of RES, our modelling does not suggest a major reduction in prices there either.

Exhibit 59: Nordic wind and solar capacity, GW



Source: Goldman Sachs Global Investment Research

Exhibit 60: Nordic share of wind and solar as a percentage of total capacity



Source: Goldman Sachs Global Investment Research

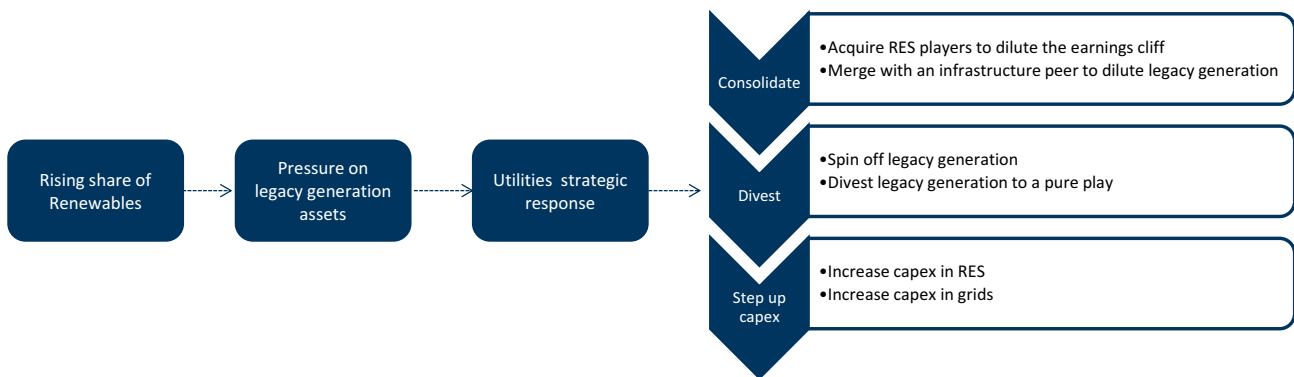
Corporate strategies will have to respond to the new scenario

To prevent such disruptive force, we believe utilities would have to modify corporate strategies. We highlight three main moves that could partly mitigate the earnings cliff previously described.

- **Consolidate.** Companies with a large earnings cliff could merge with (or acquire) players characterised by a larger exposure to infrastructure assets (grids, renewables).
- **Divest.** Some management teams might decide to divest or spin off legacy generation assets ahead of the cliff; if so, we believe this would have to happen fairly imminently (ie 1-3 years) to avoid a major contraction in valuation multiples, as the market may begin to discount such a scenario.
- **Step up capex.** Increasing investments in renewables would support profits and help dilute the contribution from legacy assets.

Exhibit 61: Rising renewables’ share is likely to trigger major corporate response

List of options for utilities to tackle the rising threat of renewables



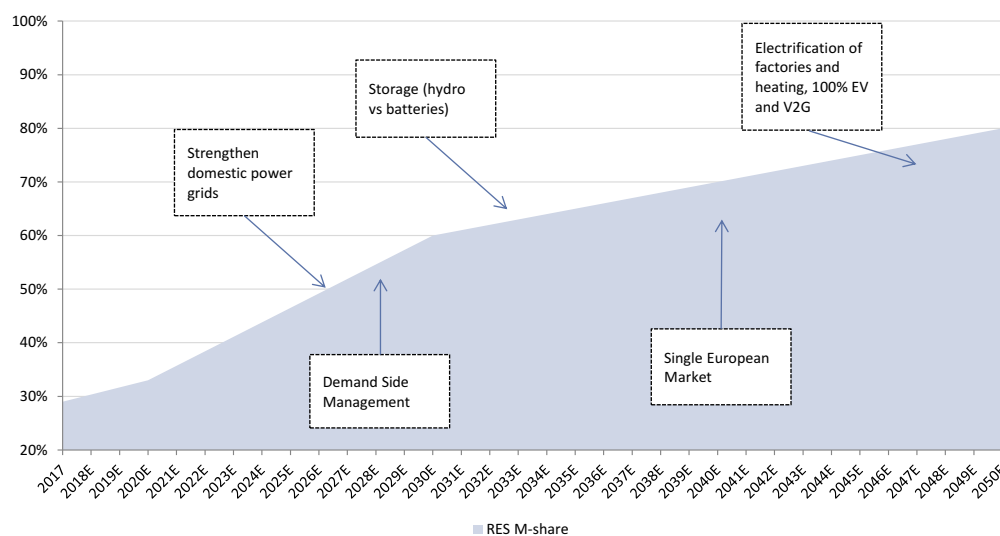
Source: Goldman Sachs Global Investment Research

The roadmap to maxing out power from renewables

This report is the first of a franchise series that will explore the milestones to monitor the rise in solar (and wind) in the power mix, and the move towards 80% electricity from renewables, in line with the target set by Germany for 2050.

Exhibit 62: The roadmap to maxing out power from renewables implies multiple challenges and has wider implications across the entire economy

Roadmap to 80% power from RES



Source: Goldman Sachs Global Investment Research

To get there, we believe a number of issues would have to be addressed, hereby listed:

- **The status of the domestic grids.** To get to 80% RES (output) penetration, medium/low voltage grids (distribution) would have to be fully digitalised; this would be a necessary condition to manage the output volatility and maintain stable network-voltage, to avoid blackouts.
- **The need to interconnect Europe.** Longer term, Europe would have major capacity clusters, such as: (i) solar PV in the South, (ii) offshore wind in the North Sea, (iii) hydro in the Nordic regions and in the mountains throughout Europe. Interconnecting Europe would optimise supply-management and lower the implementation costs of moving towards a 100% scenario.
- **Demand Side Management (DSM).** Sudden drops in volumes generated by wind and solar would require a more dynamic management of demand; the introduction of sensors would allow a wide range of consumers to be “interrupted” under extreme events.

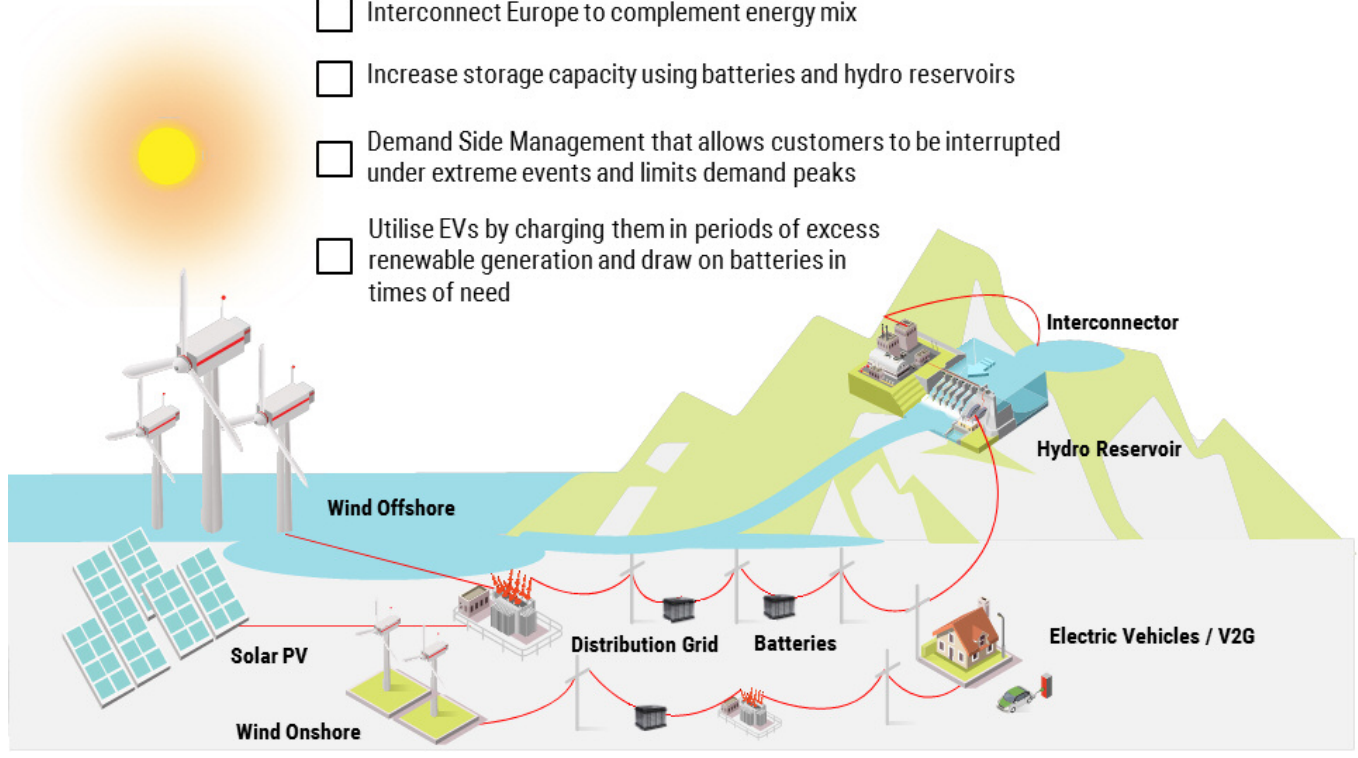
- **The role of storage: hydro reservoirs vs grid-scale batteries.** Going 100% renewables would create the rising need for storage; to contain system costs, the excess of solar production during summer-daytime might be stored in lithium-ion batteries (or whatever prevailing technology will exist by then), or could be stored in hydro reservoirs.
- **Early nuclear decommissioning.** In a world where the marginal cost of solar is heading towards €20/MWh (vs forward curves at €40-50/MWh currently) and where flexibility would be a key requirement to back up the erratic RES sources, nuclear may play an increasingly smaller role.
- **Solar curtains?** A quick fix to limit the solar excess of supply could be to disconnect these facilities from the grid. Remote management of “curtains” to cover solar modules during excess production times could become a prevailing technology.
- **The electrification of industrial processes.** Cheaper electricity may trigger a change in industrial processes, moving away from gas onto electricity. This would support electricity demand.
- **The electrification of transport and V2G.** A wide penetration of electric vehicles could serve a dual purpose: (i) cars could be recharged cheaply during periods of excess RES generation, and (ii) EVs could ultimately act a portable storage device. Turning 2bn cars into electric would create a portable 60 GW storage fleet across the globe.
- **The electrification of heating.** Cheaper and clean electricity could accelerate the switch from gas to electric heating. As buildings account for c.40% of energy consumption, this would have major repercussions on gas consumption vs electricity.

Exhibit 68: The roadmap to maxing out renewables in the energy mix passes through grids digitalisation, storage and demand side management

The roadmap in maxing out renewables in the energy mix

New large-scale PV plants and onshore wind projects now produce energy at or below the cost of conventional power stations, while the costs of offshore wind are falling fast as turbines increase in size. Here are the other most important items on the to-do list of what's needed for Europe to max out its renewables penetration:

- Fully digitalise power grids
- Interconnect Europe to complement energy mix
- Increase storage capacity using batteries and hydro reservoirs
- Demand Side Management that allows customers to be interrupted under extreme events and limits demand peaks
- Utilise EVs by charging them in periods of excess renewable generation and draw on batteries in times of need



Source: Goldman Sachs Global Investment Research

Introduction to solar PV and its impact on power economics

This section of the report provides concise, non-technical summaries of the key concepts underlying our analysis.

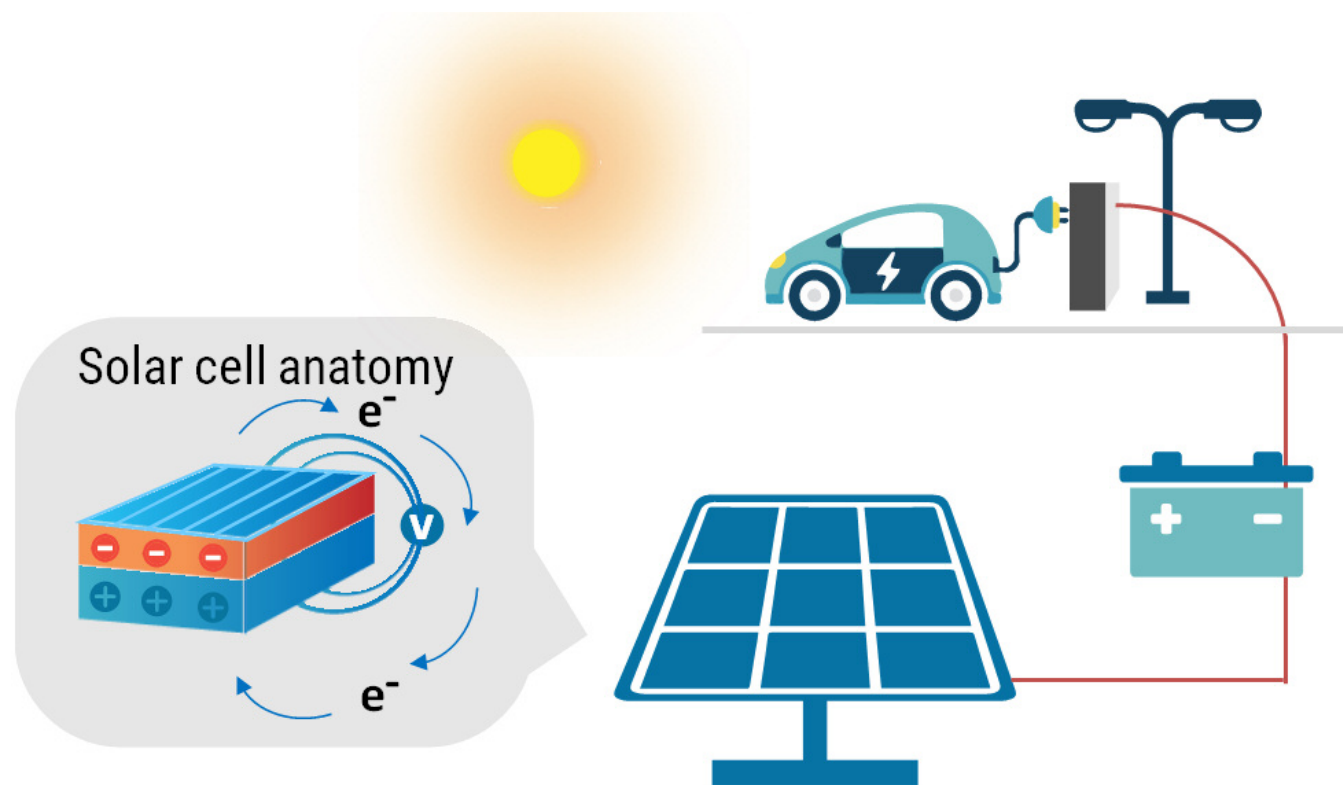
How do we convert sunlight to power?

Solar Photovoltaic (PV) technology uses solar panels (technically called modules) to convert sun rays into electricity. Each solar panel is made up of smaller solar cells made of silicon - a semiconductor that is the second most abundant element on Earth, and is derived from sand (created over billions of years from silicate rocks and quartz). Each solar cell is made up of two types of silicon layered onto each other - a negatively charged one with an extra electron for each atom of silicon, layered against a positively charged one which instead is missing an electron in each of its atoms.

When sun rays hit the panel, their energy stimulates the additional electrons to move around in search for a free space on an atomic orbit to settle on. A conductive metal junction between the two layers of silicon collects all the extra electrons from the negatively charged layer of silicon and allows them to move across to the positively charged one, generating electrical current.

Exhibit 69: How sunlight is converted to power

Illustration of a solar cell, panel and inverter



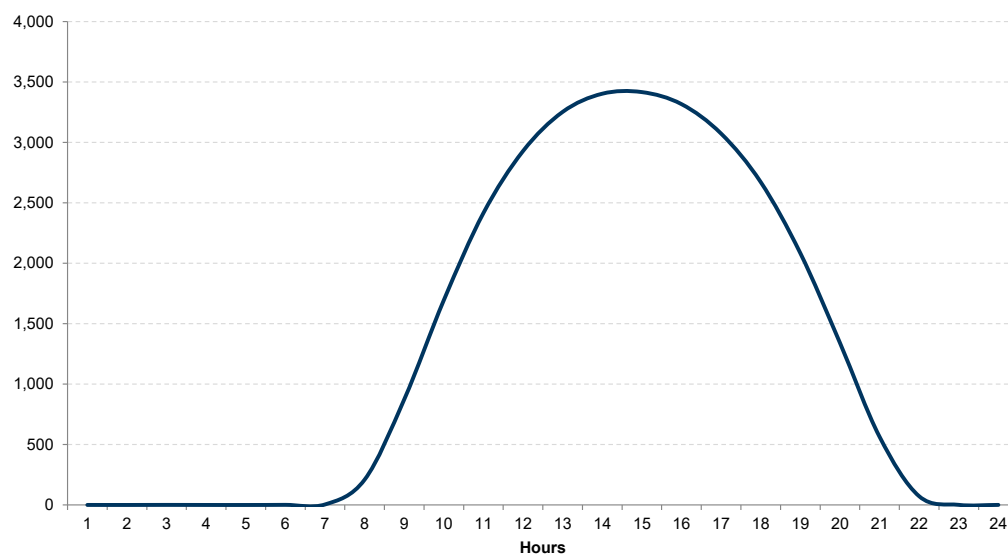
Source: Company data, Goldman Sachs Global Investment Research

How does solar PV output vary?

Solar's main limitation to providing baseload power is its intraday variability: its availability is high during daytime and zero at night; both aspects create challenges. In countries characterised by a sizeable solar PV fleet (Italy for instance), some areas might experience a structural solar oversupply during summer daytime, while the market during night-time might become quite tight, especially during hot/dry summer evenings. Exhibit 65 shows the hourly load for July 2016 in Spain (using maximum daily output). Yet, the actual frequency of the power produced changes almost constantly, as it depends on the intensity of light/sunshine. This implies that rising solar penetration would require additional investments in the grid, to strengthen its stability. The output seasonality during summer/winter and day/night could also suggest that integrating solar with storage may become the modus operandi over the medium/longer run.

Exhibit 65: Solar PV production peaks in the early afternoon but goes to zero during the night

Average daily production profile for solar PV in Spain, July 2016



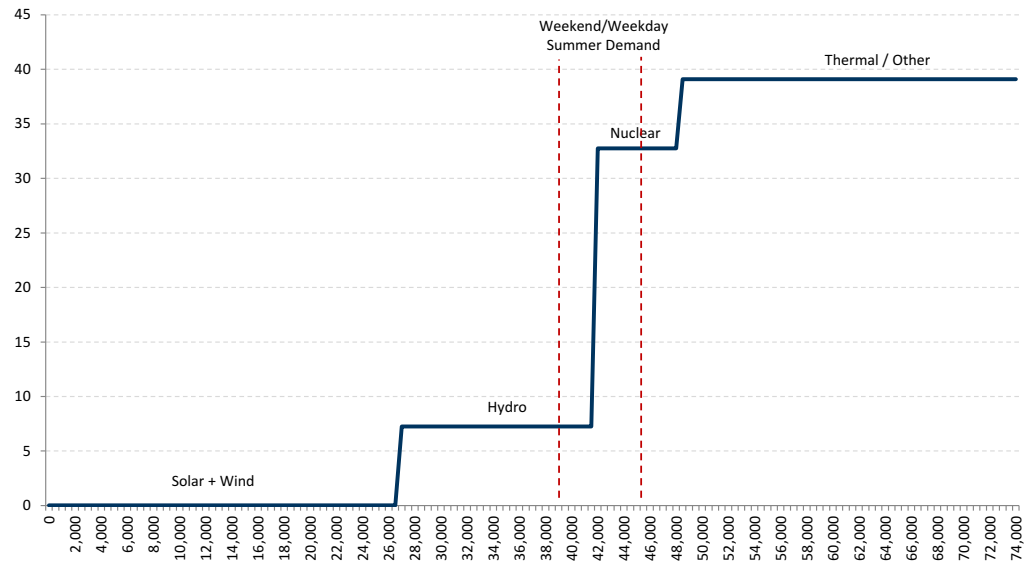
Source: Goldman Sachs Global Investment Research, REE

What is a generation supply curve?

In power generation, a supply curve allows the ranking of power plants by profitability from the cheapest (to the left hand side) to the most expensive. Normally, this curve is based on variable cash costs, as these are the typical avoidable expenditures if a plant doesn't run; for instance, cash variable costs of gas plants include fuel (ie, the commodity) and carbon (ie, carbon certificates). Exhibit 66 shows a supply curve for Spain during daytime in summer.

Exhibit 66: Spanish supply curve shows that thermal would no longer be needed by 2030 during summer daytime

Spain supply curve 2030E (variable costs in €/MWh on Y-axis, MW on X-axis)



Source: Goldman Sachs Global Investment Research

What is the levelised cost of energy (LCOE)?

The LCOE is a methodology to estimate the actual cost of generating electricity from a power plant. It is used to estimate break-even points and IRR models. To estimate the LCOE, we add up all the costs of a facility. For instance, for solar we sum up: investment costs (ie depreciation), operating expenses and cost of capital (ie target return on investment), and then divide the addition of these costs over the life of the plant (typically, 30 years) by the output generated over the same timeframe.

What is a PPA?

Power purchasing agreements (PPAs) are long-term power offtakes between a power generator and a client. Typically these are signed by large corporates that wish to source electricity, increasingly from green sources. PPAs are also the norm in some emerging markets. This scheme grants a fixed and predictable top line for a power producer.

How do you forecast merchant power prices?

To forecast power prices for a typical period “t”, we proceed in several steps: (i) we forecast hourly or seasonal demand in “t” by observing historical patterns; (ii) we project capacity evolution and estimate the supply curve, (iii) we estimate the production from each facility, to match supply/demand, (iv) we estimate variable costs by technology, (v) we estimate the marginal technology throughout the year, to derive what technologies are “price setting” (also known as “the marginal plant”), (vi) we estimate the margins that thermal plants may achieve over and above their variable costs. By weighting these hourly prices, we can estimate the weighted average power price forecast for any year.

Disclosure Appendix

Reg AC

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