# The Rising Sun

**Disruption on the horizon**

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# Foreword

The third edition of the Rising Sun is inspired by the clear trend of renewable energy emerging as a mainstream energy source globally within the next decade. In addition, the edition draws from the recent developments that have taken place in the solar PV cost curves and what those mean for the fast-growing Indian economy.

In our first edition of the Rising Sun released in May 2011, we had forecasted grid parity during 2017-18 in an aggressive scenario. In the second edition of the Rising Sun released in September 2012, we forecasted a solar power market potential of 12 GW by 2017. The aggressive growth and evolution of the sector has been broadly in alignment with our forecast, in fact a little bit more aggressive overall.

The rising solar power trends has been clear in markets like Europe and the U.S. and a sense of disruption is being felt by traditional generators and utilities over a period of time. What has been particularly interesting is the rise of distributed generation in the west, primarily that of rooftop PV. This ushers in a paradigm change for the traditional utility industry and for system planners. The future electricity system may be characterised by large amounts of variable renewables and storage with smart grids that will integrate different technologies. This scenario needs to be understood and prepared for. These technologies are 'exponential technologies' – meaning their advent would be faster than we anticipated and could cause disruption if preparation for them is not adequate.

These global developments present great opportunities for India, especially in light of the government's vision to provide affordable and sustainable power to all citizens. The Government of India has laid down its ambitious vision for the renewable sector, especially solar. Some of these global developments indicate that we may be on course to achieve this vision provided we understand the implications, and gear up to efficiently plan for this fundamental shift and change.

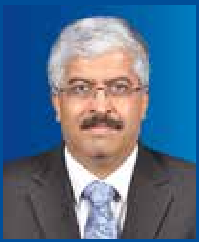
This change is also very timely, as unlike the OECD economies, we need to build over 50 per cent of the electrical infrastructure that needs to be operational by 2030. Adopting measures that would help us 'leapfrog', would help get us there faster.

Through this report, we would like to sensitise different stakeholders about this great opportunity. We seek to create awareness among these stakeholders about the changes the road ahead entails and the measures they need to take to avoid large disruptions. This change may have implications for the coal sector, for conventional generators, for distribution and transmission utilities and for system planners as key stakeholders.

We have articulated these implications in this report and would like to instigate a debate on how different stakeholders should respond. This report also highlights bottlenecks that could prevent this vision from becoming a reality and steps to help mitigate them effectively.

Lastly, this report is not about solar versus coal. India needs to harness all its resources to their best potential for its energy security.

We hope this report helps the key stakeholders in the energy eco-system to assess the opportunities provided by solar as well as introspect on the implications this will have on India's energy landscape as well as on their business.



**Arvind Mahajan**
**Partner and Head**
Infrastructure, Government and Energy

**Manish Aggarwal**
**Partner and Head**
Energy and Natural Resources

# Table of contents

# Key terminology

## Grid parity

The threshold at which a solar power system supplies electricity to the end user, at the same price as grid-supplied electricity. Grid parity will be different for different states and different end user applications.

## Grid integration costs[1]

The integration of wind and solar generators into power systems results in 'integration costs[2]' for grids which include costs for balancing services, more flexible operation of thermal plants, and reduced utilisation of the capital stock embodied in the infrastructure, among other things.

## Levelised tariff or 'Levelised Cost of Electricity' or 'LCOE'

The tariff for each year during a term of a PPA (Power Purchase Agreement) is discounted by applying the discount factors (based on the discount rate), and such aggregate discounted value for the term of the PPA is divided by the sum of such discount factors to calculate the levelised tariff.

## 'Learning curve' effect or 'Price Experience Factor' or 'PEF'[3]

The 'learning curve' effect builds on historic experience that with each duplication in the total number of modules produced, the price per module falls by a certain factor. This factor is called PEF.

## Feed-in-Tariff (FiT)

A feed-in tariff (FiT, feed-in law, advanced renewable tariff or renewable energy payments) is a policy mechanism designed to encourage the adoption of renewable energy sources. Under a feed-in tariff, eligible renewable electricity generators (which can include homeowners and businesses) are paid a regulated price for any renewable electricity they produce.

## Plant Load Factor (PLF)

PLF for a given period is the actual sent out energy during the period, expressed as a percentage of installed capacity multiplied by the number of hours in that period.

# Key economic assumptions

Market sizing done for India unless specified other wise

Cost projections correspond to real values in 2015, unless otherwise specified

**3.5** per cent — WPI Inflation (2015-25)

**64** — Exchange rate (INR/USD in 2015)

**11** per cent — Long-term domestic interest rate (2015)

**20** per cent — Plant load factor

**16** per cent — Return on equity for solar projects (Post tax)

[1] Hirth, Lion, Falko Ueckerdt & Ottmar Edenhofer (2015): "Integration Costs Revisited – An economic framework of wind and solar variability", Renewable Energy 74, 925–939.

[2] IRENA (2015), Renewable Power Generation Costs in 2014.

[2] Fraunhofer ISE (2015): Current and Future Cost of Photovoltaics. Long-term Scenarios for Market Development, System Prices and LCOE of Utility-Scale PV Systems. Study on behalf of Agora Energiewende.

# Disruption on the horizon

In the last six years since the launch of the National Solar Mission (NSM), the rise of solar energy seems to have beaten the expectations of most analysts. On a nominal basis[4], today we can say that we have reached grid parity with coal power in India. India has reached an important landmark with respect to its energy sector. In this paper, we look at the following questions:

**01** How might the sector evolve from here?

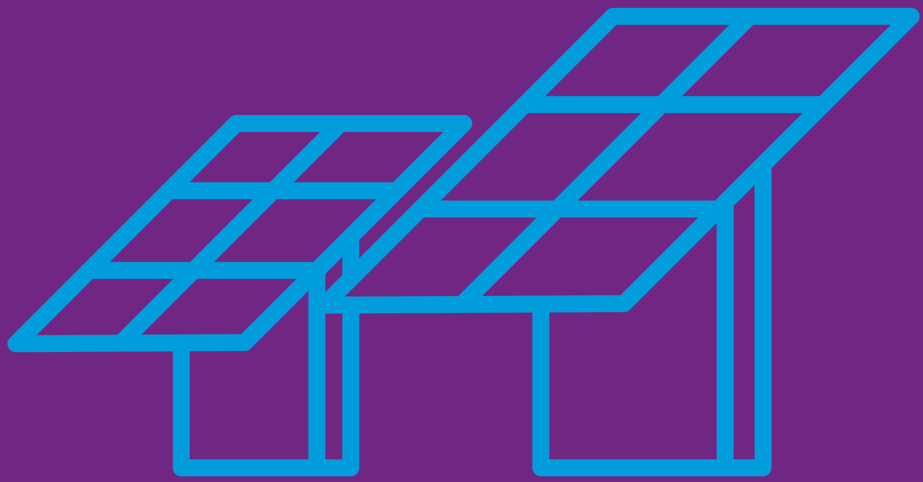
**02** What does the achievement of grid parity mean to power utilities?

**03** What does this mean for the fossil fuel industry?

**04** What are the implications for the different stakeholders?

This paper shows a potential path the sector can follow in the run up to 2024-25.

* This paper shows a potential path the sector will follow in the run up to 2024-25: all our findings/forecasts are based on extensive research, analysis and discussions with industry players. However, these predictions are dependent on a variety of factors, and changes in them could impact these forecasts in the future.

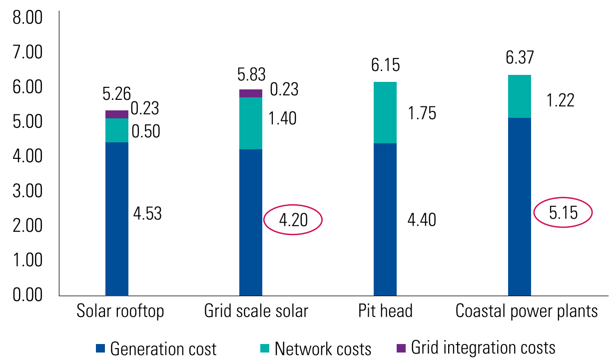


[4] Without considering costs of grid integration and balancing resources - based on KPMG in India's analysis, 2015.

# Executive summary

Solar power price declines have beaten the expectations of most analysts since the beginning of 2015.[1] In the ongoing NTPC solar park tender, solar prices have breached the INR 5/kwh and this is a landmark for the energy sector. Today, in India, solar prices are within 15 per cent[2] of the coal power prices on a levelised basis. While this may not fully capture costs such as grid integration costs for solar, our analysis suggests that even after considering the same, solar prices would be competitive with coal. Our forecast is that by 2020, solar power prices could be upto 10 per cent lower than coal power prices.

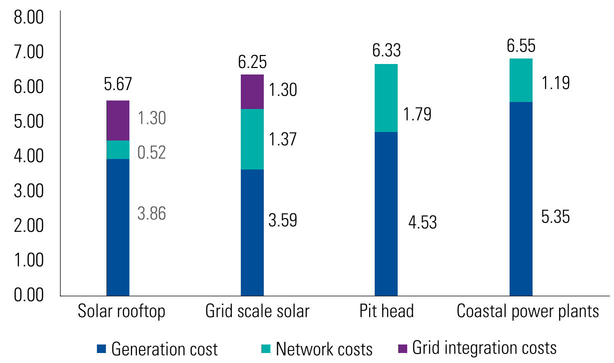
Figure 01: LCOE at the consumers' end in 2020 (INR/kWh): Solar power will be more economical than conventional coal tariffs




Source: KPMG in India's analysis, October 2015

By 2025, solar is expected to have scaled up significantly to be a major energy source. Coal would respond in order to be competitive, and we may see an equilibrium emerging between solar and coal after considering the costs of integration.

Figure 02: LCOE at the consumers' end in 2025 (INR/kWh): Solar power and coal tariffs are at parity levels




Source: KPMG in India's analysis, October 2015

We forecast a solar generation price of INR 4.20/kWh by 2020 and INR 3.59/kWh by 2025 (at 2015 price levels). As per our estimates, the market penetration of solar power could be 5.7 per cent (54 GW) by 2020 and 12.5 per cent (166 GW) in energy terms by 2025. Along with wind power, renewable energy could constitute a significant 20 per cent of our power mix in energy terms by 2025.

The bigger disruption which we are yet to see may come from the solar rooftop business. This will be supported by a rise in storage technologies, and together they could change the energy landscape. Solar rooftop power, today, is already competitive compared to grid power; however, it requires net metering support. Though, going forward, this will change due to the significant evolution that is expected in storage technologies.

[1] http://www.livemint.com/Industry/NBy4Gjh97Qj9xNJwkgLS0H/Solar-power-tariff-touches-record-low-of-Rs463-with-SunEdis.html
[2] KPMG in India's analysis

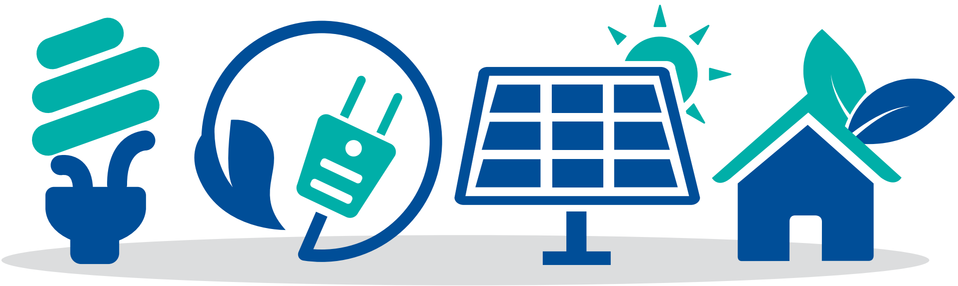
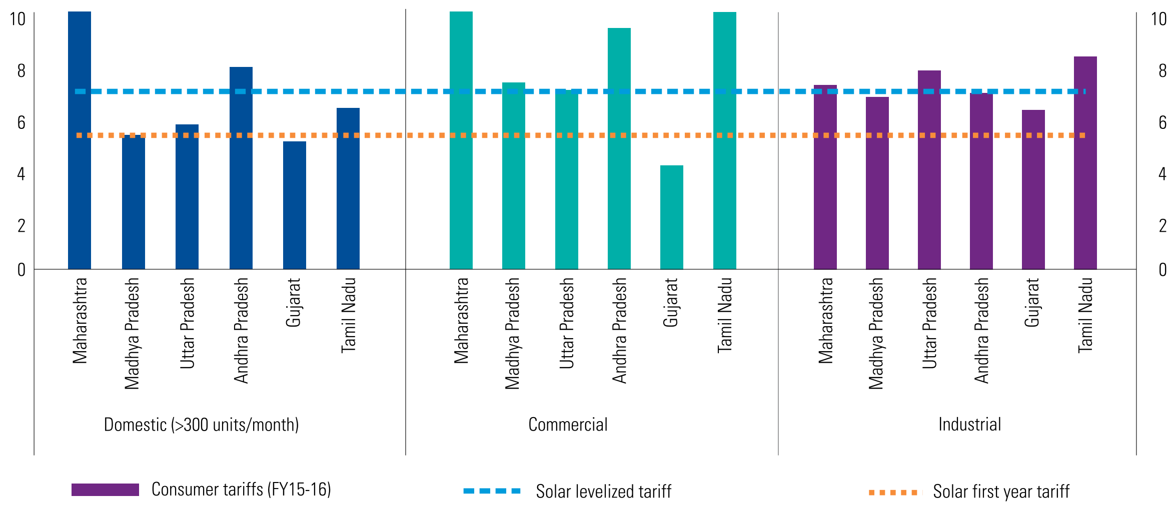
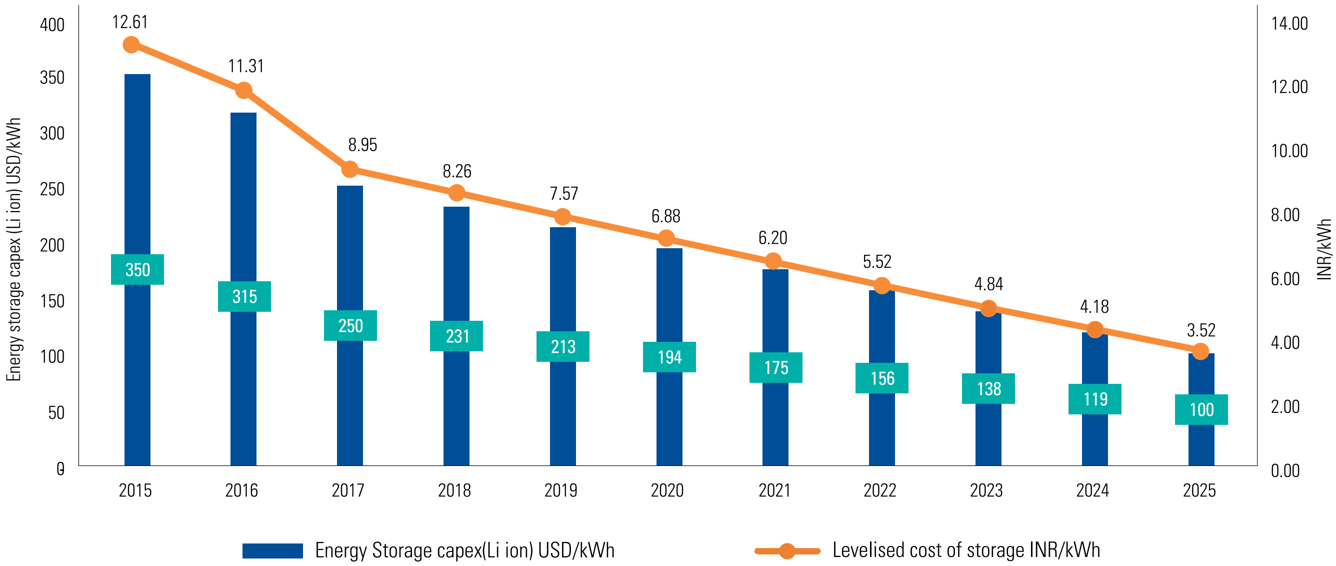


Figure 03: Solar PV is already economical for certain consumer categories: INR/kWh




Source: Tariff order of various states during 2015-16, KPMG in India's analysis, October 2015

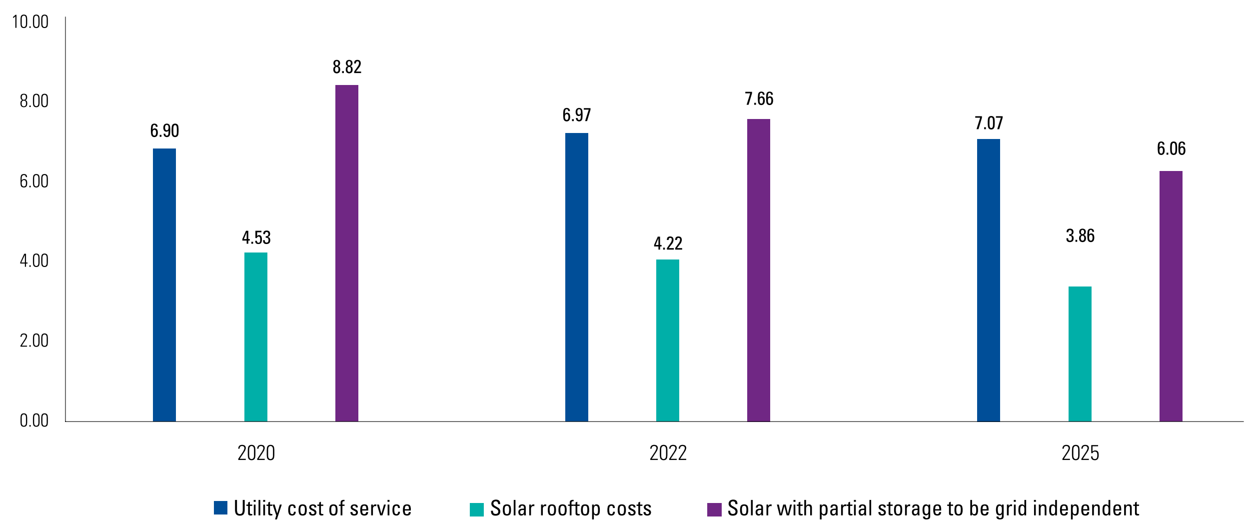
Figure 04: Lithium ion-based storage costs are expected to decline rapidly: INR/kWh




Source: Tesla Motors, U.S. Department of Energy's EV Everywhere Grand Challenge, KPMG in India's analysis, October 2015

As per our forecast, solar rooftop power combined with storage will be cheaper than grid power after 2022 for a large section of consumers, and at that time we may see a large shift towards rooftop power. We would like to call this transition, the arrival of the 'Solar House'.

Figure 05: A grid independent 'Solar House' is likely to be a reality after 2022: LCOE in INR/kWh




Source: Tariff order of various states during 2015-16, KPMG in India's analysis, October 2015

We estimate the solar rooftop market to reach 10 GW by 2020 and 49 GW by 2025.

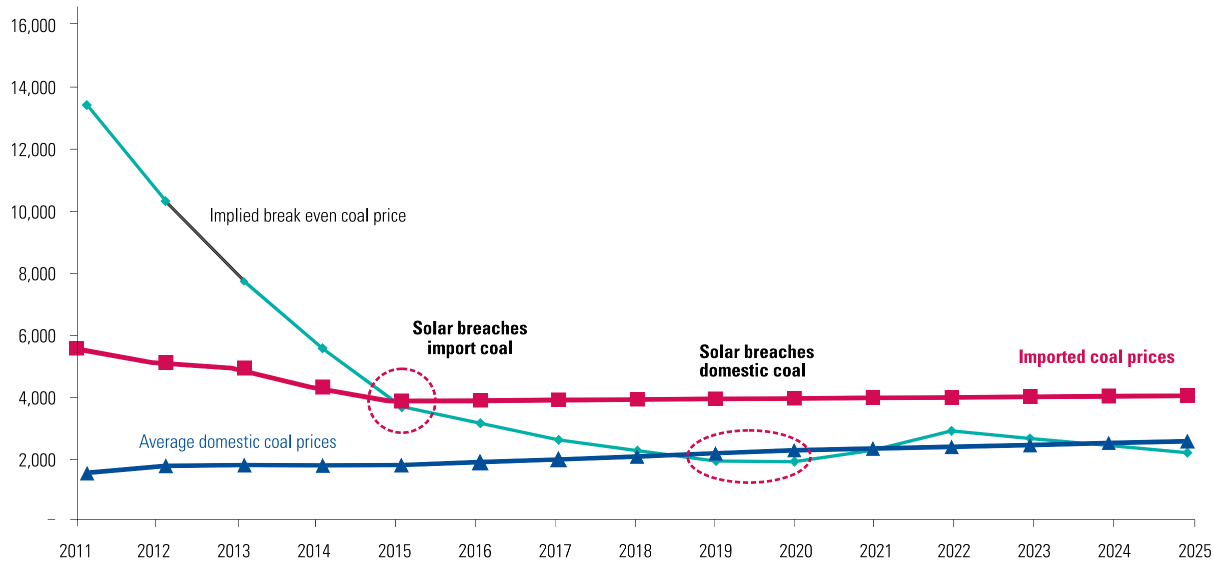
Solar power is likely to help displace 275 million tonnes of carbon emissions in 2025 and contribute towards India's intended nationally determined contribution (INDC) targets. India aims an emission intensity reduction of its GDP by 33 to 35 per cent by 2030 from 2005 levels[3] and solar power is likely to contribute four (4) per cent towards this target.

The scale up and competitiveness of solar power could disrupt coal-based generators and the coal sector, if advance action is not taken. The disruptive force will likely be felt from 2017 onwards, and will accelerate post 2020.

States, that are already promoting solar (and also wind power) aggressively, could see the PLFs of conventional coal generators fall by as much as 10-15 per cent by 2020, as solar replaces coal-fired generation during the day. This effect will accelerate post 2020 when large amounts of solar power would get added annually (an average of 20 GW per year from 2022 onwards in our estimate). Post 2022, coal prices could begin chasing solar prices, and not vice versa as we see today. Eventually, coal may have to respond by reducing its cost structure and an equilibrium is likely to develop, but this transition could be challenging for the coal sector if early preparation is not done.

[3] India's Intended Nationally Determined Contribution – Press Information Bureau, Government of India, October, 2015

Figure 06: From 2020, solar power will influence domestic coal pricing: INR per tonne



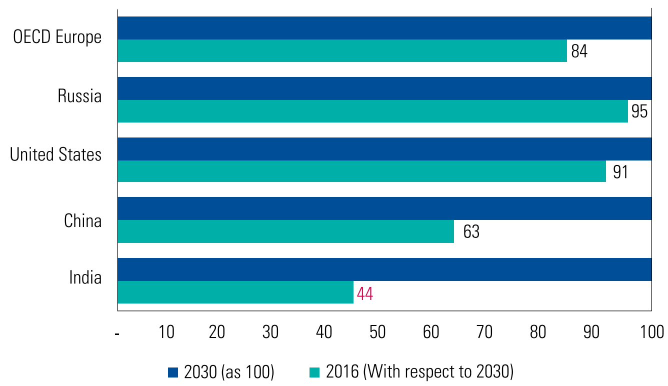

Source: Coal India Limited (CIL) Annual Reports, Indonesia Coal Price Reference – HBA, KPMG in India's analysis, October 2015

Different stakeholders need to understand the potential and possible implications of this disruption, and be prepared to face it.

- To start with, India's energy sector needs a new planning paradigm which takes into account a high Renewable Energy (RE) scenario going forward. High RE, storage and smart grids will come together within the next 10 years. The government needs to focus on significant strengthening of the planning infrastructure including planning policy, institutions, resources and protocols. The right incentives for investments in grid integration of solar and balancing services should be put in place early. The government should now think of promoting storage technologies in the same way it did for encouraging the use of solar power through the National Solar Mission in 2009.

  A benefit India has is that new electrical infrastructure is expected to be built in the next 15 years that will exceed what is standing on the ground today i.e. we will more than double the infrastructure. Planners need to note that this provides an opportunity to leapfrog and accordingly choose the right pathway to scale up the power sector in the nation.

Figure 07: India needs to install more than half of its total capacity requirement(s) by 2030



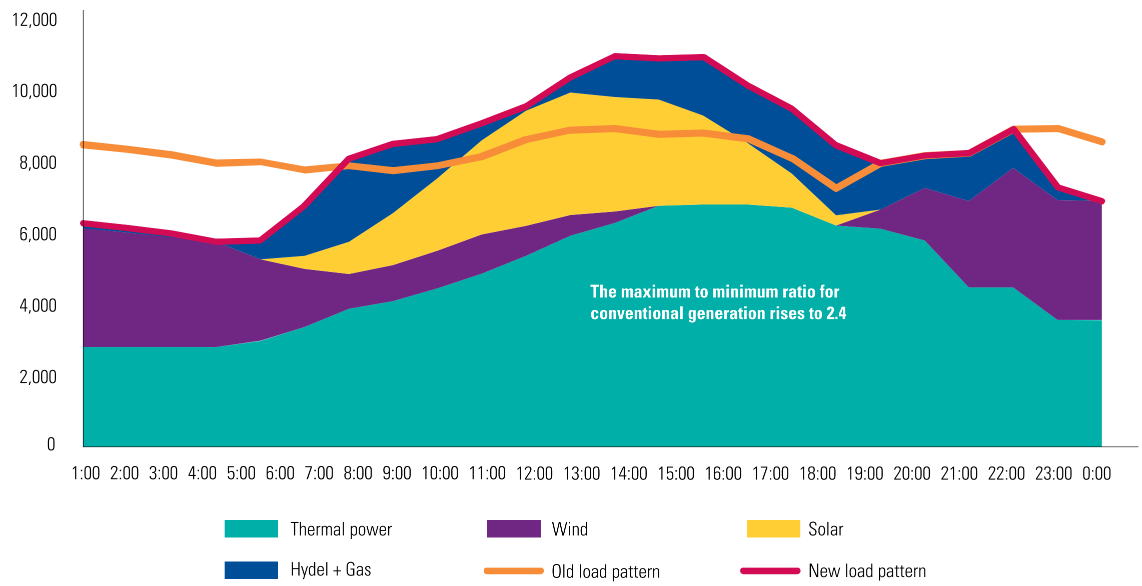

Source: 'Energy and Climate Change' - World Energy Outlook Special Report by IEA in 2015, KPMG in India's analysis, October 2015

- For power discoms, competition finally arrives in the form of distributed rooftop solar power combined with storage. Utilities could begin to lose customers and will likely get into a vicious spiral of rising subsidy support requirements to stay afloat or risk losing customers due to rising residual costs. They need to hedge themselves by getting into solar rooftop business and develop new revenue models based on their customer relationships. Importantly, they need to closely scrutinise the cost commitments they are making today for the long-term. Apart from the efficiency impact due to AT&C losses, discoms will have to seriously look at their power procurement portfolio and how they are contracting for incremental capacities. The cost structure of new capacities should be closely scrutinised before commitments are made. We find this level of rigour currently lacking especially for capacities created by state gencos.
- The coal sector is expected to start coming under significant pressure from 2022 onwards as solar would have achieved scale. To meet this challenge, the coal sector needs to focus on cost efficiency and flexibility to meet the various scenarios of demand. Apart from solar, various other factors such as slowing growth in China, emergence of energy efficiency on the demand side and fall in the commodities cycle, could lead to pressures on imported coal prices as well. This in turn could put pressure on Coal India Limited (CIL)'s costs, as many users may find imports cheaper.

  CIL should undertake a detailed study to address long run costs, and also bring flexibility into its operations to adjust to the different scenarios of demand and prices when the need arises.
- India will need to add significant conventional generation capacities to meet its growing demand needs. In fact, with respect to the base scenario, conventional generators will need to contribute 60 per cent of incremental capacity needs up to 2025, with solar contributing between 20-25 per cent, and another 15 per cent coming from wind. However, these additional capacities will need different attributes from the ones seen so far such as: 1) flexibility in generation (in terms of ramp rates and minimum thresholds) and, 2) low fixed costs with higher variable costs would be preferred, rather than vice versa.

  For new generators, flexibility should be a necessary criterion. Further, gas and hydro-based generators should be planned strategically to meet the needs of flexibility. An illustrative load curve for a southern state in India is shown below to indicate the ramping requirements from conventional power sources to meet the residual load in 2019. Within a day, the maximum residual load to be met from thermal power generation plants could be 2.4 times the minimum residual load.

Figure 08: Effective load curve management will require flexible generation sources: (MW in May, 2019) A simulation for a day's power curve in a southern Indian state




Source: KPMG in India's analysis, October 2015

A framework for encouraging private investment in ancillary services is currently absent and this needs to be addressed urgently.

- Finally, for investors, the solar sector represents immense opportunities. True differentiated business models can be developed in the area of solar rooftops. Opportunities in storage solutions and ancillary services including demand response and grid balancing would also emerge strongly. Given the large ramp up needs of the sector, availability of domestic capital could be a challenge. Investors should look at tapping new sources of capital such as international funds and domestic bond markets.

A few of the factors that could delay the achievement of the scenario we have projected here, include the following:

- A global recessionary scenario that makes the availability of capital difficult for solar (which is almost four times as capital intensive as coal on a per kWh basis). This scenario could also correlate with a fall in fossil fuel prices, and thereby delay the attractiveness of solar.
- A rise in alternate carbon-efficient energy options such as shale gas or clean coal technologies.
- A delay in the evolution of storage technologies that are critical to absorb vast amounts of renewables.
- A hard landing of the Chinese economy leading to a disruption in its solar manufacturing ecosystem.
- Grid and utility preparedness to absorb vast amount of renewables in India.
- A deep depreciation in the Indian currency which would make solar less attractive compared to coal.

We see solar power becoming a mainstay of our energy landscape in the coming decade. It is expected to be disruptive which could be beneficial in the long run:

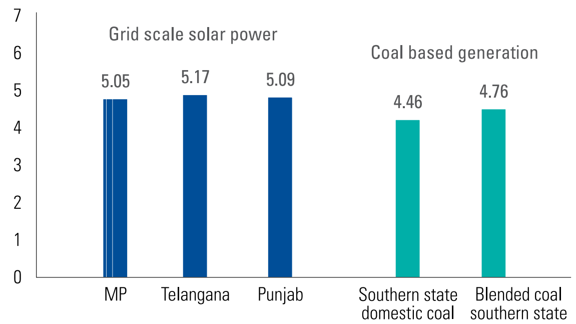
- On the one hand, solar power is a clean form of energy and will reduce coal consumption over a period of time. This will help in climate change control for a country like India. It will help protect our environment and forests, as much of our coal reserves come from under forest land.
- The quality of our distribution grids leaves much to be desired, especially in our rural areas. Direct-to-home power through solar rooftop and storage will help bypass poor quality grids.
- Finally, the evolution of storage technologies could lead to the advent of electric vehicles, and with that a mitigation of oil consumption. This could eventually help increase India's energy self-reliance and save significant foreign exchange for the country. From a global perspective, it will help increase energy security for many nations, and hopefully help resolve or prevent the many wars fought over natural resources.

# Grid parity: has it been achieved?

If we compare the levelised tariffs under the recent conventional (coal power) bids with the tariffs discovered in the last few solar tenders, we see that the recent solar bids received are within 15 per cent of the coal power tariffs. We call the solar tariffs as nominal tariffs because solar power, being variable and carrying some intermittency, does not have the same attributes as coal power. There are additional costs called 'grid integration costs' that need to be taken into account.

Figure 01: Comparison of levelised tariff from recent bids for coal and solar power

Discovered solar PV tariffs are fast approaching coal based generation tariff levels: INR/kWh (levelised at state periphery)




Source: KPMG in India's analysis, October 2015

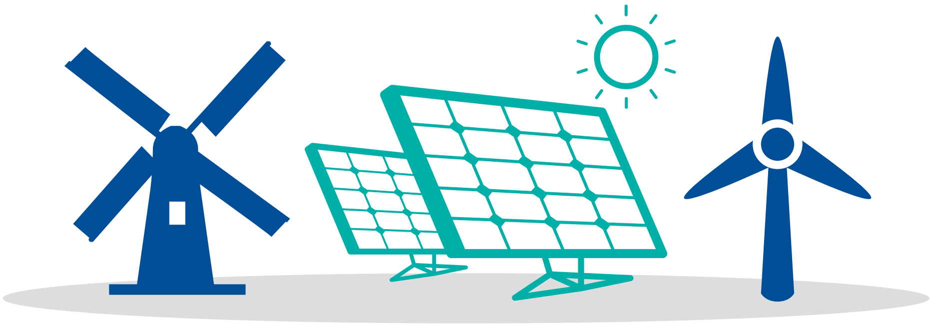
The grid integration costs tend to vary based on the level of penetration of solar power in the grid. At low levels of penetration, the costs of grid integration for solar power are negligible but increase with rise in penetration. The grid integration costs can be split into balancing, variability-related and transmission-related costs[1]. Balancing costs refer to costs associated with the uncertainty surrounding the level of generation against the anticipated advance schedule. Variability-related costs refer to the shape of the supply curve and arise due to the fact that alternate capacity arrangements have to be made in order to meet the peak demand when the solar curve cannot address the same. Transmission costs relate to costs arising out of lower utilisation of the first mile and associated transmission assets, since solar power plants operate at lower PLFs.[2]

## Grid integration costs

In order to estimate the true cost of solar power, we considered how the costs of grid integration described above might impact the achievement of grid parity. It is difficult to accurately estimate the grid integration costs; however, we made the following estimates based on the range of values observed from different[3] studies conducted around the world:

- Grid integration costs is likely to be low till we reach a level of 45-50 GW of solar penetration (our estimate year is 2020). This is because of the fact that we have a high level of flexible loads (for example, agriculture water pumping loads contribute to nearly 18 per cent of our total demand and amount to almost 50 GW)
- Even after the demand adjustments take place to accommodate solar power (to the extent of 45-50 GW), solar penetration would still be less than 20 per cent of the day time peak demand. At this level, integration costs are considered low.
- Beyond 2020, grid integration costs would increase; however, we see the emergence of various alternative solutions to address these costs. These include development in storage technologies such as grid scale (pumped hydro and compressed air), distribution level (battery storage and other technologies such as flywheels), thermal storage and solutions such as demand response and better forecasting tools.

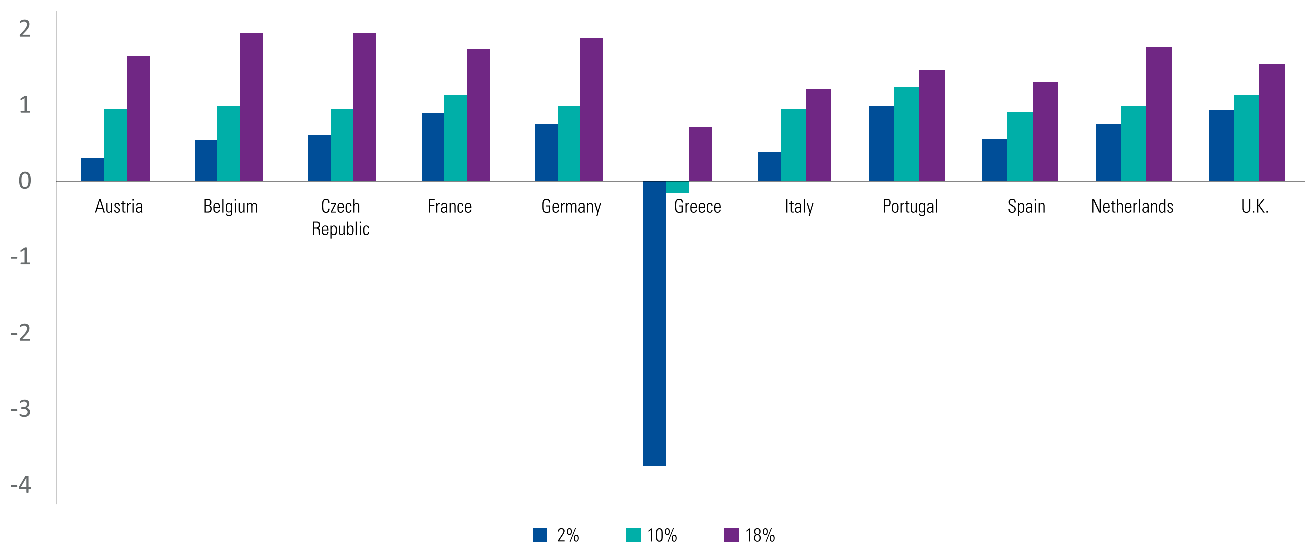
[1] Hirth, Lion, Falko Ueckerdt & Ottmar Edenhofer (2015): 'Integration Costs Revisited – An economic framework of wind and solar variability', Renewable Energy 74, 925–939.
[2] Hirth, Lion (2015): 'The Market Value of Solar Power: Is Photovoltaics Cost-Competitive?' IET Renewable Power Generation 9(1), 37-45doi:10.1049/iet-rpg.2014.0101.
[3] IRENA (2015), Renewable Power Generation Costs in 2014.



- Based on a range of values observed globally (see Figure 2), we estimate the costs of grid integration to lie in the range of INR1-2/kWh beyond 2020. We use this level to assess some of the key trigger points for solar scale up and its impact on other energy sources.
- While the grid integration costs may not be very high till 2020, it would still require preparedness in terms of balancing resources and flexibility in generators.

Figure 02: Grid integration costs of solar power in other countries (INR/kWh)

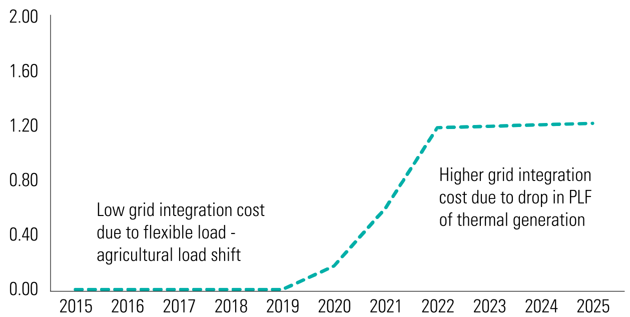
In comparision to LCOE, grid integration costs for solar PV remain modest :(penetration as a per cent of total energy met)




Source: Direct Costs Analysis related to Grid Impacts of Photovoltaics; D. Pudjianto, P. Djapic, J. Dragovic, G. Strbac Imperial College London, September 2013.

Figure 03: Solar grid integration cost projections for India

Grid integration costs increase with rise in solar PV penetration: INR/kWh




Source: KPMG in India's analysis, October 2015

## Solar PV cost roadmap

Solar PV costs globally, have declined more than 75 per cent[4] during the last 10 years. This reduction has been due to factors such as falling raw material costs (especially silicon costs), technology improvements, increasing efficiency and rising scale of solar PV installations across the world.

The 'learning curve' effect is expected to continue to influence the cost trajectory of solar PV. The historical photovoltaic learning curve suggests the rate to be around 23 per cent based on empirical evidence during the last 35 years.[5] While the future learning rates might be lower than the historical rates, some of the cost reduction drivers are as follows:

### Efficient use of materials

Reduction in costs could be achieved through usage of thinner wafers and better recycling of consumables through diamond wire technologies. Some companies are also working on direct conversion of poly-silicon to wafers without ingot slicing which could substantially reduce the overall wafer costs. Reduction in silver consumption from 100 μg to 40 μg per cell by 2025[6], because of new developments in pastes and screens (10 per cent of non Si-cell price), is also likely to contribute towards cost reduction. Moreover, in cells, substitution of silver with copper and replacement of aluminum frames in modules with plastic or other cheaper material would also help reduce costs.

### Improved manufacturing processes

As per ITRPV[7] roadmap, usage of larger ingot sizes increasing from the current 800-1000 kg to around 1400 kg, and the increasing throughput of machinery could lead to cost reduction.

### Cell efficiency

A big factor that could influence the lowering of solar panel costs will be the efficiency of the solar cells. The last few years have seen an annual improvement in the average efficiency by around 0.5 per cent.[8] This is expected to continue as the theoretical efficiency of single junction silicon solar panels is 29 per cent compared to the current average multi-crystalline silicon solar panels efficiency of 16-17 per cent. Some solar panel producers are already commercially shipping panels with 20-22 per cent efficiency.[9] Improvement in efficiencies may occur through better cell printing technologies and improvement in cell to module power ratio.

The usage of newer technologies such as micro-inverters and increase in system voltages could also increase the power output efficiencies of solar panels. Development of multi-junction solar cells can further increase the efficiency to ~30-50 per cent; however, the manufacturing costs of such panels will have to be reduced in order to make them competitive. There are also chances that a technology breakthrough in usage of organic materials or thin film technology can lead to a faster than expected reduction in costs.[10]

**Based on the above, our base case scenario for solar PV module prices is at a level of USD 25-30 cents/watt by 2025 from around 50 cents/watt now.**

### Solar inverters

The price of solar inverters has also decreased substantially from around USD 1.1 /watt in 1990 to around 9 cents/watt in 2015. The learning curve effect for solar inverters based on empirical data evidence during the last 25 years has been 19 per cent. Like solar modules, solar inverter prices are expected to keep falling due to more efficient usage of materials, improved circuit design and usage of better power semiconductors. Our base case scenario for solar inverter prices is around USD 5-7 cents/watt by 2025.[11]

### Balance of System (BOS) components

The main improvement in the balance of system (BOS) costs could come indirectly through the increase in solar panel efficiency. Labour, mounting structure, land and fencing costs tend to decrease due to module efficiency improvements due to reduction in module area. A doubling of module efficiency could effectively lead to a 50 per cent decrease in the above costs. Usage of some of the other components such as electricals and cabling will also reduce as a result. The other factors that could contribute to the decline in BOS costs are the use of cheaper raw material substitutes, better design, increasing scale of solar power plants and usage of automation. Our base case scenario for the BOS prices is USD 25-30 cents/watt by 2025.

**Based on the above, our base case scenario for solar power price in India is between INR 3.5 to 3.7/kWh by 2025 (at 2015 constant prices).**

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[4] IRENA (2015), Renewable Power Generation Costs in 2014.

[5] Fraunhofer ISE (2015): Current and Future Cost of Photovoltaics. Long-term Scenarios for Market Development, System Prices and LCOE of Utility-Scale PV Systems. Study on behalf of Agora Energiewende

[6] International Technology Roadmap for Photovoltaic (ITRPV)

[7] International Technology Roadmap for Photovoltaic (ITRPV) 2014 Results

[8] http://www.forbes.com/sites/peterdetwiler/2013/07/16/as-solar-panel-efficiencies-keep-improving-its-time-to-adopt-some-new-metrics/ 6 November 2015, http://e360.yale.edu/feature/will_new_technologies_give_critical_boost_to_solar_power/2832/ - 6 November 2015

[9] 'SunPower E-series Residential Solar Panels' – http://www.sunpowercorp.co.uk/datasheets, 'HIT Photovoltaic Module – HIT Power 240S', Panasonic - http://panasonic.net/ecosolutions/solar/hit/

[10] F. Dimroth, M. Grave, P. Beutel, U. Fiedeler, C. Karcher, T.N.D. Tibbits, E. Oliva, G. Siefer, M. Schachtner, A. Wekkeli, A.W. Bett, R. Krause, M. Piccin, N. Blanc, C. Drazek, E. Guiot, B. Ghyselen, T. Salvetat, A. Tauzin, T. Signamarcheix, A. Dobrich, T. Hannappel and K. Schwarzburg, Wafer bonded four-junction GaInP/GaAs//GaInAsP/GaInAs concentrator solar cells with 44.7% efficiency. Progress in Photovoltaics: Research and Applications, 2014. 22(3): p. 277-282, https://www.ise.fraunhofer.de/en/press-and-media/press-releases/press-releases-2014/new-world-record-for-solar-cell-efficiency-at-46-percent - 6 November 2015

[11] Fraunhofer ISE (2015): Current and Future Cost of Photovoltaics. Long-term Scenarios for Market Development, System Prices and LCOE of Utility-Scale PV Systems. Study on behalf of Agora Energiewende

## Grid parity economics

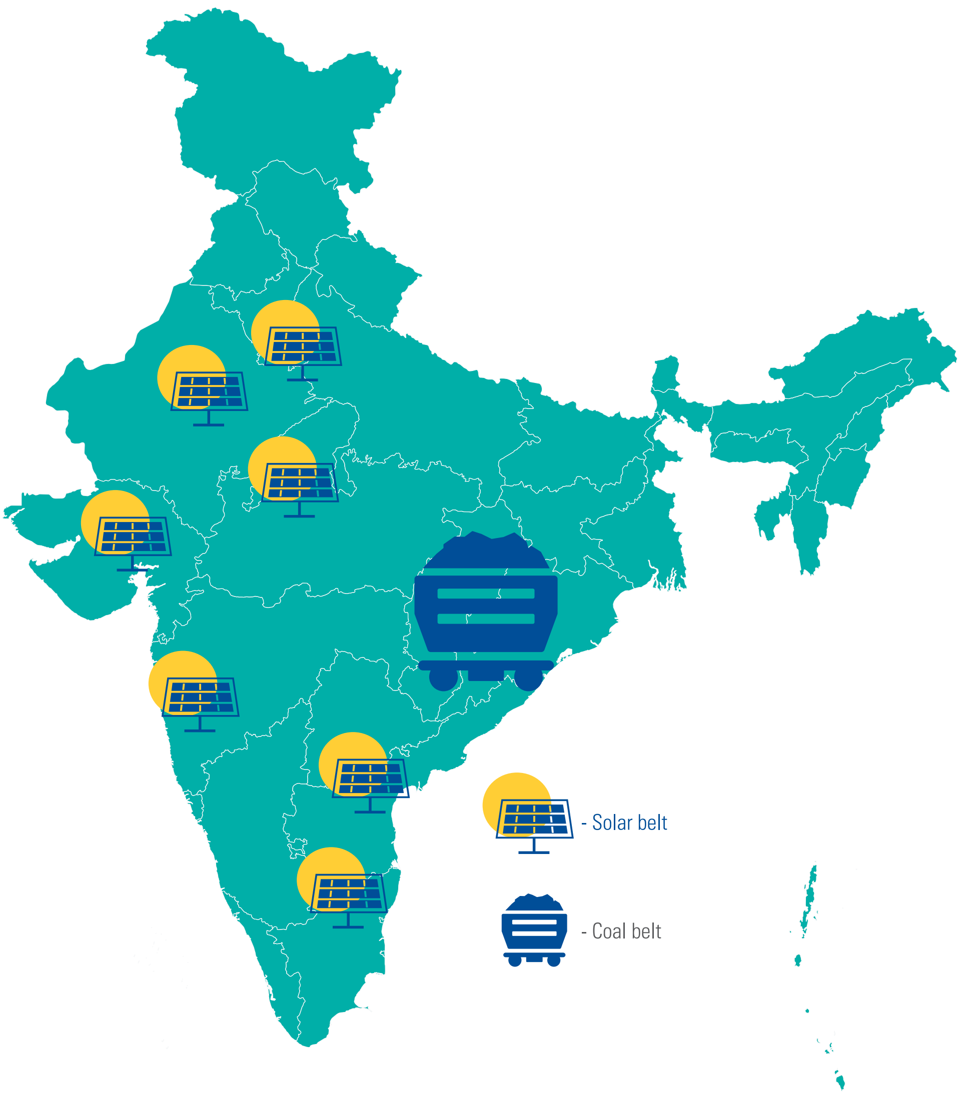
We calculate the grid parity economics based on the cost of power delivered at a point at 11kV voltage in the network, from different sources of generation: 1) Rooftop solar 2) Grid scale solar (within states) 3) Pithead coal plants and 4) Coastal coal plant using imports.

Grid parity has been derived based on the sum of three components:

- Levelised bus bar cost of generation
- Transmission and distribution costs (network charges)
- Grid integration costs applicable to solar power to handle its variable and intermittent nature.

While computing the transmission charges, we recognise that the solar resource rich states are closer to the load centres and lie in the western and southern parts of the country, while the pit head coal-based generation resources are more than 1000 km away from the load centres as shown in Figure 04.

Figure 04: Image showing the proximity of solar rich states with that of the major load centres in North, West & South

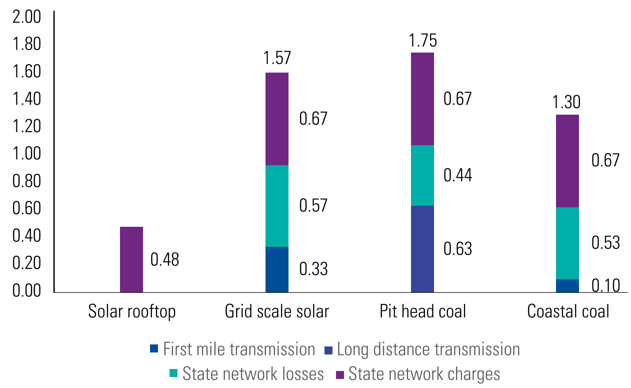



Source: KPMG in India's analysis, October 2015

Figure 5 shows the transmission and distribution costs (including losses) collectively called 'Network Charges' for power delivered to the end consumer from the four sources as explained earlier.

## Figure 05: Transmission and network charges for supply of power to the end consumer

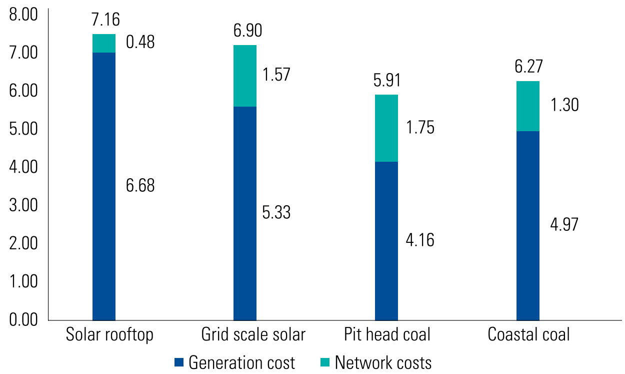
Electricity transmission costs varies across different sources: INR/kWh




Source: Tariff orders by electricity regulatory commission(s) in 2014-15, KPMG in India's analysis, October 2015

## Figure 06: Tariff comparison at the consumer-end including grid integration costs for solar power for 2015

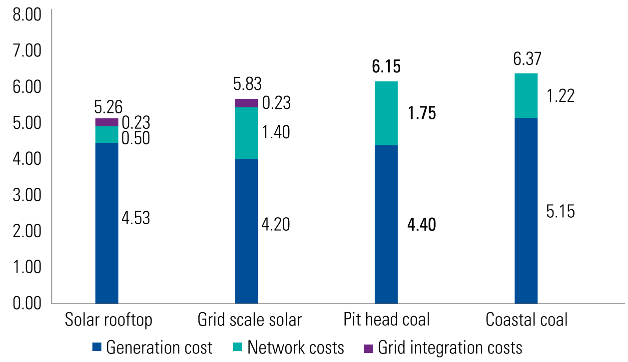
LCOE at consumer end in 2015 (INR/kWh): Solar power is marginally higher than conventional coal tariffs




Source: KPMG in India's analysis, October 2015

## Figure 07: Tariff comparison at consumer-end including grid integration costs for solar power for 2020

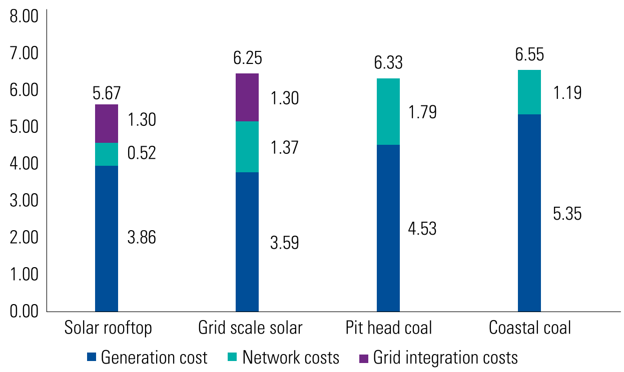
LCOE at consumer end in 2020 (INR/kWh): Solar power will be more economical than conventional coal tariffs




Source: KPMG in India's analysis, October 2015

## Figure 08: Tariff comparison at consumer end including grid integration costs for solar power for 2025

LCOE at consumer end in 2025 (INR/kWh): Solar power and coal tariffs are at parity levels




Source: KPMG in India's analysis, October 2015

**Key assumptions:** State Transmission & Distribution (T&D) Charges : INR 0.54 /kWh in 2015-19; T&D losses 11 per cent (2015-16); Transmission line (400 KV) cost: INR 17 to 22 million per KM; Transmission S/S cost: INR 1200 million.

The fall in solar prices is not an India specific phenomenon. Prices of solar power have been coming down internationally and are expected to decline further.

Table 01: Recent global solar prices

| Country | Year | Price (Cents) | Price in (INR/kWh) |
|---|---|---|---|
| Jordan | 2015 | 6.13 | 3.98 |
| Dubai | 2015 | 5.98 | 3.89 |
| Germany | 2015 | 10.09 | 6.56 |
| Brazil | 2015 | 8.42 | 5.47 |

Sorce: MENA solar outlook -2015, 'Recent Facts about Photovoltaics in Germany' - Fraunhofer Institute for Solar Energy Systems ISE -2015, KPMG in India analysis

We can thus say that solar costs currently are within 15 per cent of coal power costs, and are expected to remain below coal power costs in 2020 and in parity with coal in 2025 even after considering integration costs.

# What share of the power mix would solar achieve in the next decade?

We have estimated the capacity creation of solar power based on the total capacity addition needs of the power sector and the share of the incremental capacity that solar could take as follows:

Table 2: Incremental electricity requirement and share of solar

| Particulars | Units | 2019-20 | 2024-25 |
|---|---|---|---|
| Incremental electricity requirement | million units | 478,910 | 1,130,649 |
| Share of solar energy in total incremental energy | per cent | 20 | 25 |

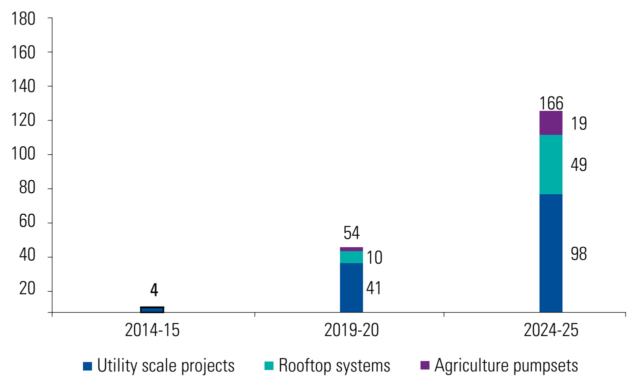
Source: 18th Electric Power Survey (EPS) of Central Electricity Authority (CEA), KPMG in India's analysis, October 2015

The solar power potential has been estimated considering demand from three segments: utility scale, rooftop and agriculture. For estimating the rooftop potential, an incremental adoption rate has been considered based on the grid parity economics. We expect that the adoption rate will keep increasing with the rising wedge between the solar rooftop costs and the average utility tariffs. Demand from agricultural pumpsets has been made considering an increasing share of solar powered pumpsets being deployed to meet the demand for new connections, driven by economic as well as social considerations. Post 2019, we believe that the replacement market from existing pumpsets to a solar powered efficient pumpset will pick up as well.

For estimating the grid scale potential, the residual electricity requirement after deducting the total contribution from solar rooftop systems and agriculture pump sets from the total electricity requirement has been estimated. The total solar power potential in India could reach around 54 GW by 2020 and accelerate rapidly to reach around 166 GW by 2024-25.

Figure 09: Estimate of the solar market in India

Solar PV is set to witness an exponential growth in the coming decade in India: GW




Source: KPMG in India's analysis, October 2015

**Key assumptions:** Incremental annual energy requirement in India: 95,783 MU (Avg. for the next five years); Growth in energy demand: 7 per cent (2016-25); EPS projections of electricity requirement have been used; Share of solar in meeting the incremental electricity needs is 20 per cent (2015-2020) and 25 per cent (2020-25).

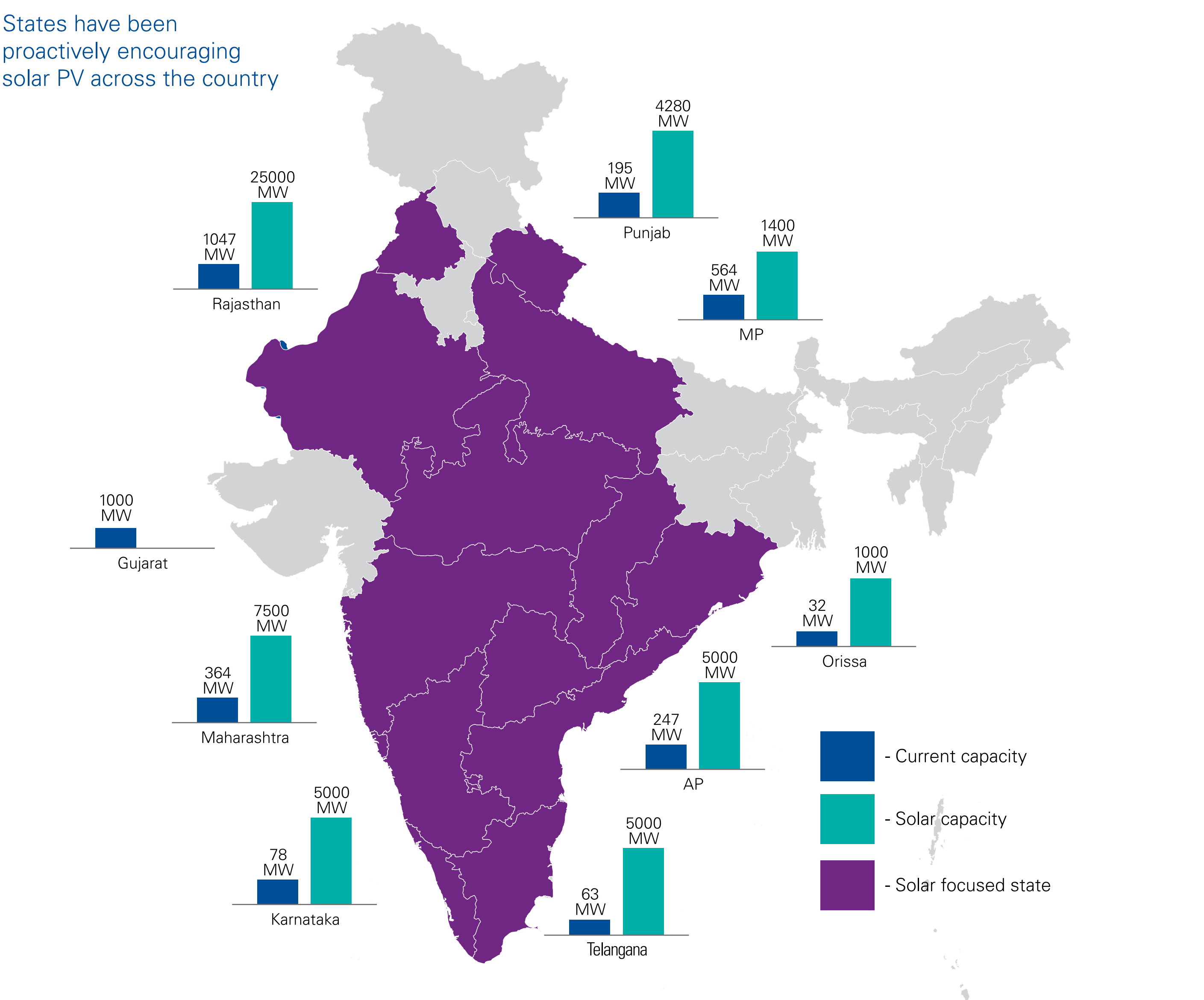
Solar power is expected to increasingly displace the additional power requirements in a phased manner. Today, the contribution of solar power capacity is around 0.6 per cent in the total electricity consumption of India. By 2019-20, we expect the solar energy contribution to be around 5.7 per cent of the total electricity generation and is likely to be around 12.5 per cent by 2024-25.

# What will be the likely drivers of the market demand in the future?

### The pull factor in the near term

In the last 18 months, the market off-take has been dominated by the 'tender pull', for which the motivational force is meeting the power requirements of state discoms. Varying motivational factors have driven states to set individual solar capacity targets.

Figure 10: State wise target and current installed solar capacity




Source: Invest Rajasthan, Ministry of New & Renewable Energy (MNRE), Government of India, KPMG in India's analysis, October 2015

While currently many states in India have made a claim to be power surplus or sufficient, going forward, they will need to add or contract additional capacities to meet load growth needs. In this scenario, cheap solar power after considering integration costs can be a viable option.

Some of the key factors driving solar adoption include:

- Economics and short gestation: The near parity with coal and the short gestation period makes solar power attractive to adopt to meet the growing demand needs of the states.
- Energy security considerations: States that are not blessed with fossil fuel resources like Punjab, Haryana and UP can leverage the solar potential to reduce dependence on external sources.
- Lower development stage risks: Solar power does not entail the same level of risks related to environmental factors, fuel supply and logistics as coal, and therefore is perceived as less risky.
- Day time supply of power: Solar power can provide the state with the ability to meet the power demand of farmers during the daytime, and given its short gestation period vis-à-vis coal, it can address an important political objective.

The above drivers can create a strong 'pull factor' for states to continue to procure solar power through tenders.

### The 'push factor' in the longer term

The 'push factor' is expected to emerge when solar companies sell solar power directly to customers. This can happen when policies and regulation do not constrain direct customer access. While regulations in many states show intent to enable customer access, the on-ground experience and long-term stability of such a stance is unclear. This would be especially so when utilities begin to experience the pain of a large solar scale-up as will be discussed later in the report.

An important manifestation of the 'push factor' will be seen when solar power combined with storage becomes cheaper to the end customer compared to grid supply. When that happens, the solar industry could begin to the break free from regulatory and policy dependence. It would be difficult to stop its rise at that point. The 'push factor' would override everything else. As we discuss in the next section, this is likely to start happening from 2020 onwards as India nears the vision of achieving the 'Solar House'.

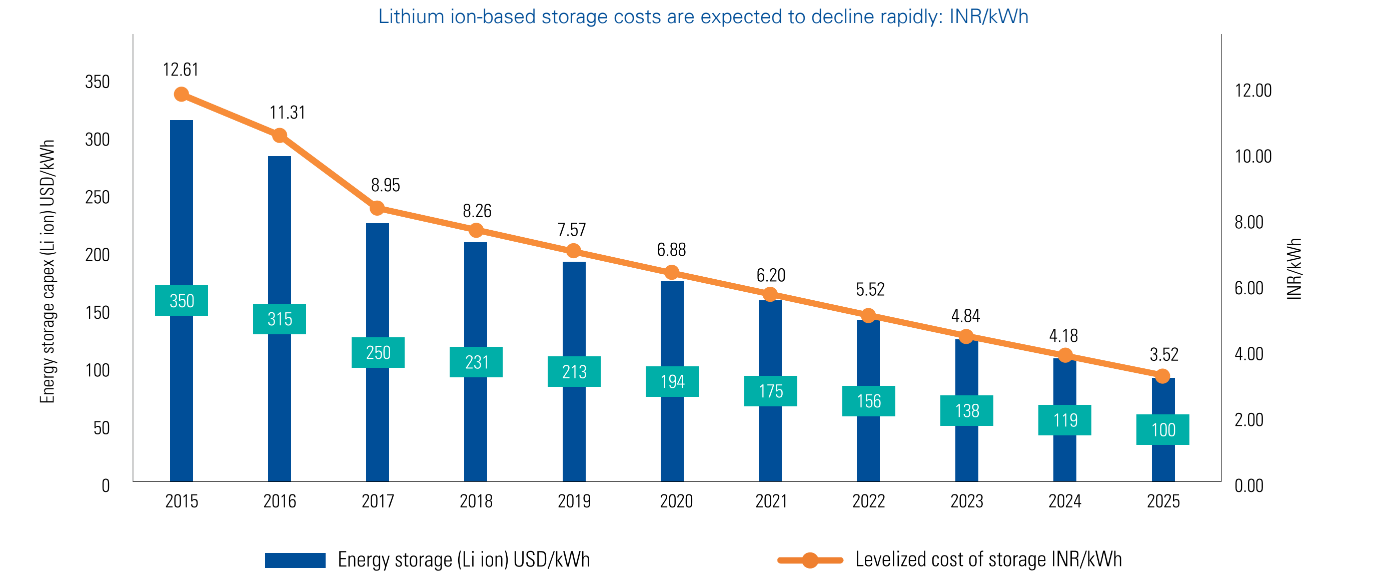
# The 'Solar House'

The concept of the 'Solar House' refers to the condition when the entire power needs of a household can be met by rooftop and on-site solar panels, which combined with energy storage, can potentially make the household completely independent of the grid. This can happen when technology will bring the cost of solar power and storage systems to below the cost of power delivered by the grid. This event has the potential to change the dynamics of the power utility-customer relationship(s) forever.

### Evolution of storage technology

Battery storage costs have reduced substantially over the last few years from over USD 1000 per kWh to about USD 350 per kWh. With increasing scale, the battery costs are expected to reduce further. The graph below indicates expected movement in the levelised cost of storage. The per unit figures represent the cost of storing and retrieving a unit of energy.[12]

Figure 11: Forecast of Li-ion battery cost and LCOE of storage




Source: Tesla Motors, U.S. Department of Energy's EV Everywhere Grand Challenge, KPMG in India's analysis, October 2015

### Illustration of the 'Solar House'

We analyse below the ability of a typical middle and high income household to meet its energy needs from solar power incident on the roof. The table below shows that the roof space for a single or two storied house is adequate to meet the entire power needs of a typical house.

Table 3:Table showing adequacy of rooftop space to meet the power demands of the entire house.

| Description | Middle income group | High income group |
|---|---|---|
| Average monthly demand (kWh) | 150 | 350 |
| Rooftop area for a typical house (sq.ft.) | 500 | 1000 |
| Rooftop suitable for solar Installation (sq.ft.) (Assuming 30 per cent) | 150 | 300 |
| Installable capacity of solar (kWp) | 1.5 | 3 |
| Average monthly generation from solar (kWh) | 200 | 400 |

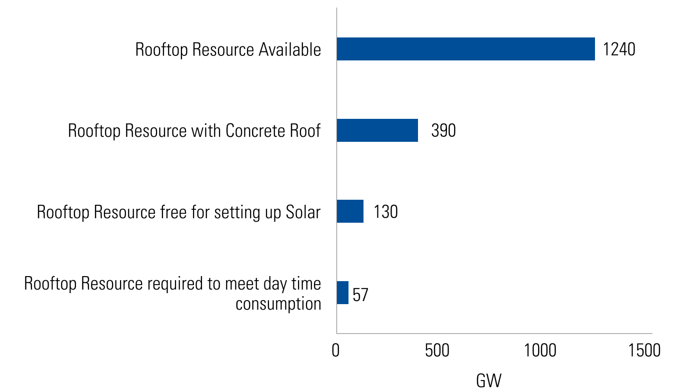
Source: KPMG in India's analysis, October 2015

[12] The EV Everywhere Challenge FY 13 Highlights, Department of Energy (DOE), U.S., http://www.bloombergview.com/articles/2015-04-08/clean-energy-revolution-is-way-ahead-of-schedule - 6 November 2015

India has large rooftop resources that can be leveraged to meet the energy requirements of households in an economic and sustainable manner.

## Figure 12: Residential rooftop potential in India (GW)

Residential Rooftop Resource Potential in India (GW)




Source: 2011 Census Data, 7th Building program for officers of the regulatory commission, IIT Kanpur (30th Jan 2015), KPMG in India's analysis, October 2015

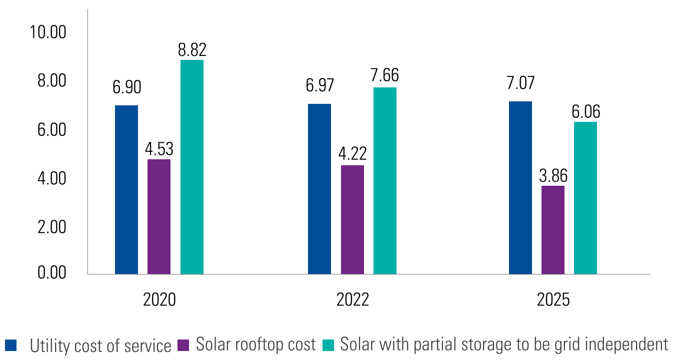
**Key assumptions:** Data as per 2011 Census, YOY Growth in Consumption = 7 per cent, 1kW Solar covers 100sq.ft. of rooftop, Rooftop available for setting up solar = 30 per cent.

In Germany, out of 40 million households, 1.4 million households have solar rooftops installed – translating to an adoption rate of 3.5 per cent (German Solar Industry Association April 2014)

The economic rationale for a partial 'Solar House' starts making sense within the next few years. With storage costs declining, the 'Solar House' concept can help consumers reduce their dependence on the grid.

## Figure 13: LCOE comparison of tariff for domestic consumers

A grid independent 'Solar House' is likely to be a reality after 2022: LCOE in INR/kWh



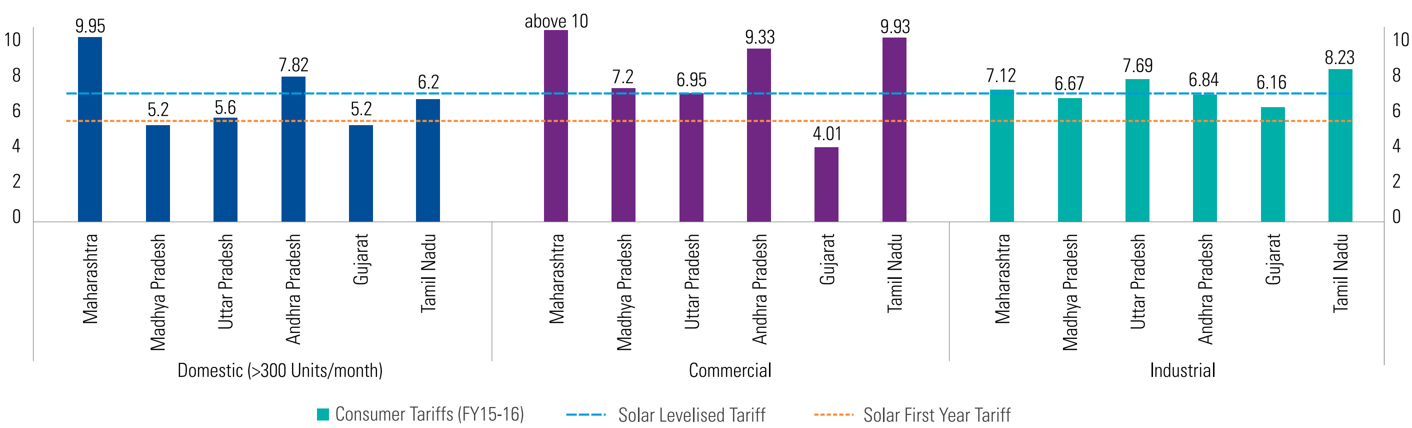

Source: Tariff orders of States, KPMG in India's analysis, October 2015

We estimate that the potential of solar rooftop is likely to increase at an accelerated pace once the storage solutions start becoming attractive post 2020.

Not considering storage, solar rooftop costs are already competitive in FY 2015-16 for many industrial, commercial and some residential customers as the graph below shows.

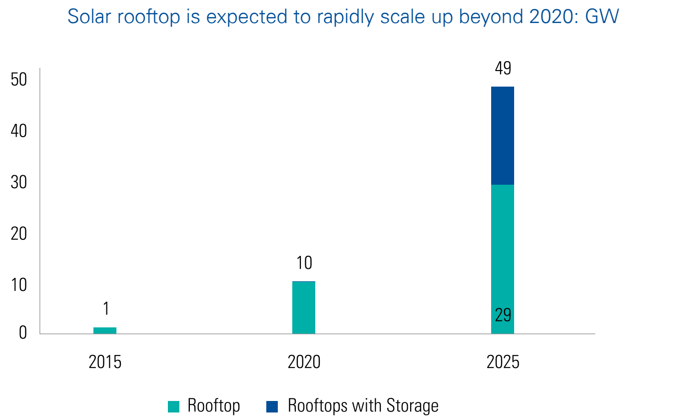
## Figure 14: Comparison between LCOE and tariff for FY 15-16

Solar PV is already economical to certain consumer categories: INR/kWh




Source: Tariff orders of states during 2015-16, KPMG in India's analysis, October 2015

Figure 15: Cumulative solar rooftop potential in India (GW)




Source: KPMG in India's analysis, October 2015

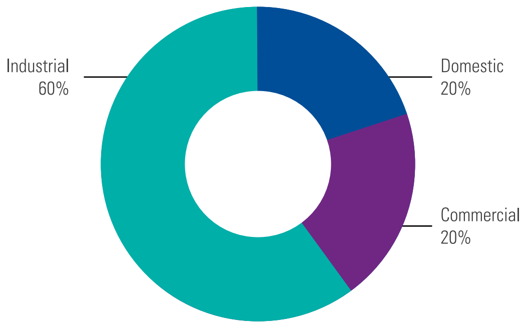
**Key assumptions:** Rooftop availability: residential (60 per cent); commercial (28 per cent); industrial (40 per cent).

We believe that the rooftop mix will be dominated by industrial consumers for the next five years, while within a decade, the domestic residential consumers could contribute to a majority of the rooftop installations.

The rooftop adoption rate for domestic consumers in India is likely to be around 3.5 per cent to reach a potential of 2 GW by 2019-20. With storage becoming an attractive option, the adoption rate is likely to increase to 20 per cent and reach a potential of around 25 GW by 2024-25.

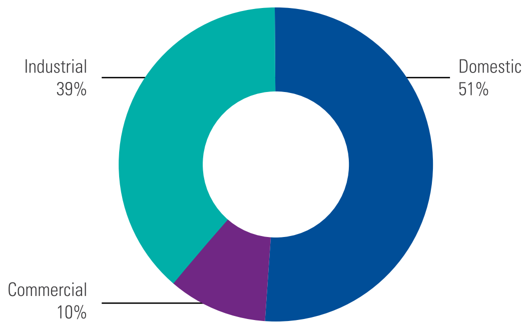
# Domestic segment is expected to dominate the solar PV rooftop market mix in the long run

Figure 16a: Rooftop potential contribution 2019-20




Source: KPMG in India's analysis, October 2015

Figure 16b: Rooftop potential contribution 2024-25




Source: KPMG in India's analysis, October 2015

The achievement of the 'Solar House' is expected to be a landmark in mankind's efforts to access energy. The 'Solar House' will help India leapfrog technologies in the area of supplying uninterrupted 24X7 energy to its citizens. When the conditions for the 'Solar House' are achieved, the the 'push' factor, can override all barriers.

# Solar pumpset market is likely to takeoff within the next five years

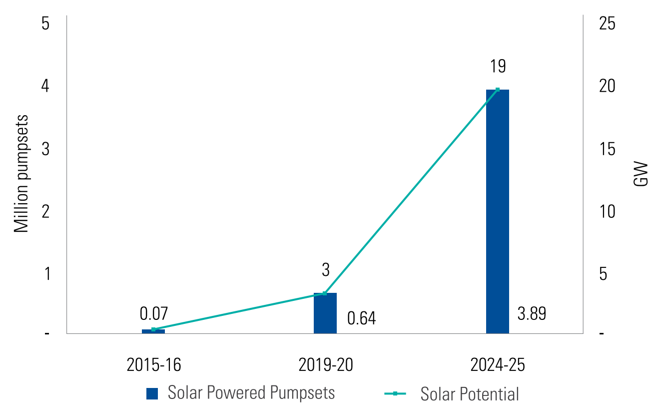
Today, India has more than 20 million pumpsets8 energised from the grid with very low average tariff realisations and high government subsidy. The power supply to farmers is erratic and the pumpset efficiency is poor. With solar prices on the decline, a model that integrates energy efficiency with a solar powered solution can help mitigate the problem. This can reduce the subsidy burden of the government and help provide day time quality power to the farmer.

The market is ripe for the introduction of new business models that leverage the benefits of tail end solar PV generation at the pumpset level and displaces the Discom's power procurement cost without an additional financial burden on the discom. A model that provides comfort to the developer based on payments linked to generation and incentivises the farmer based on payments linked to energy savings can be a win-win proposition.

Over the next few years, we believe that solar powered pumpsets will be increasingly used to meet the demand for new agricultural connections, going up annually from around 30,000 (5 per cent of new connections) to 1,50,000 (25 per cent) by 2020 and 3,00,000 (50 per cent) by 2025. We believe the existing pumpsets will also be replaced with solar powered pumpsets in a phased manner. We also estimate that the total solar powered pumpsets could reach around 0.6 million by 2020 and 3.8 million by 2025.

## Figure 17: Solar pumpset market in India

Solar powered pumpset market is set for takeoff within the next five years: (million pumpsets and GW potential)




Source: Solar powered pumpset market is set for takeoff within the next five years: (million pumpsets and GW potential)

We estimate the market takeoff can happen if the costs for a typical 5 HP solar powered pumpset reduces to around INR 3,00,000 from INR 4,50,000 today (as per KPMG in India analysis 2015). We believe innovations in product development, financing, customer acquisition and installation can lead to a cost-competitive integrated solar PV pumpset.

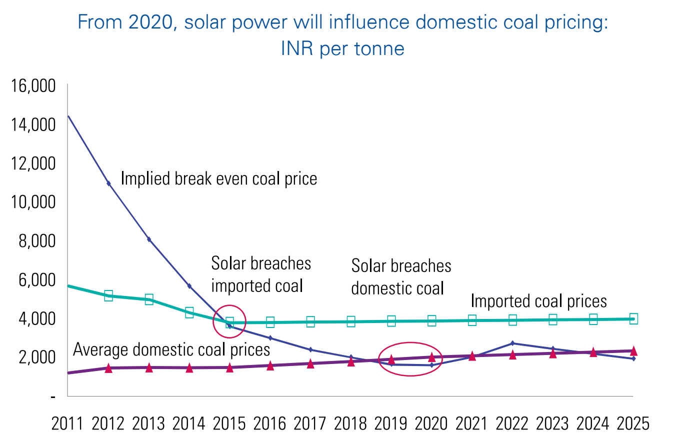
# Push back from coal

With solar prices expected to decline further, the conventional coal-based generation market is likely to face some serious competition. Given this backdrop, it is pertinent to assess the fossil fuel price dynamics over the short-term and in the long-term.

The domestic coal pricing in India primarily follows a cost plus approach. There is also a fair degree of import coal in the coal mix which is linked to international prices. Over the past five years, the domestic coal prices have seen a CAGR rise of around 6 per cent whereas the imported coal prices during the same period have declined by a CAGR of around 9 per cent.[13] Going forward, we expect domestic coal costs to increase over the next few years at a rate of around 9.4 per cent annually till 2020 in line with efforts to increase domestic supply, on account of the deteriorating geology, increase in labour costs and land acquisition costs. Thus, domestic coal prices may push up the power prices, giving a further impetus to solar based generation in India. On the other hand, the imported coal prices are expected to either remain flat or see only a moderate rise owing to the reduced demand growth from key economies. As installed solar power capacity reaches 45-50 GW by 2019- 20, it could replace the demand for around 50 million tonnes of coal which will be around 7 per cent of the total coal consumption in the power sector in India in that year. At this stage, we believe that there will be a push back from coal based power plants.

A net back computation of coal cost (i.e. price of coal that leads to the same power tariff as solar power) presents an interesting picture. From being an uncompetitive source, solar power has made rapid strides and has already achieved grid parity with imported coal and is expected to achieve parity with domestic coal by 2020. The net back computation has also been computed considering the grid integration costs of solar power. This has major implications on the future pricing power of coal.

Figure 18: Net back cost of coal projections




Source: Coal India Limited (CIL) Annual Reports, Indonesia Coal Price Reference – HBA, KPMG in India's analysis, October 2015

With attractive economics, the period between 2018 and 2022 is likely to witness large scale solar adoptions. The power utilities will likely start including solar power in their procurement mix in a big way to meet the incremental power requirements. We believe that the coal industry will push back and the coal prices will reflect not just the coal industry dynamics but also the competing solar PV net back price dynamics. Post 2022, we believe a dynamic pricing equilibrium will set in between the solar and coal sectors.

The coal sector's adjustment to the solar sector could cause some pain. To mitigate this, the coal sector will need to prepare itself and develop an efficient cost roadmap and flexibility in its operations to adjust to the various scenarios of demand.

[13] Domestic coal prices - CIL, Imported coal prices - Indonesia Coal Price Reference (HBA)

# Utility response to the solar march

**Going forward, we see the solar sector evolving in three phases:**

**Phase 1 ('Supportive' phase): Utilities supportive, everyone gains (till we reach the first 15 GW, approx. 2017)**

- This is the phase we are in now. Utilities seem to be happy to procure solar power and are also motivated by the falling prices. It meets their power demand requirements, and penetration levels are low: below 10 per cent of the daytime peak demand.
- Solar producers seem to be happy as the utilities are seen to be supportive. Discoms' financials could however be a concern in some cases.

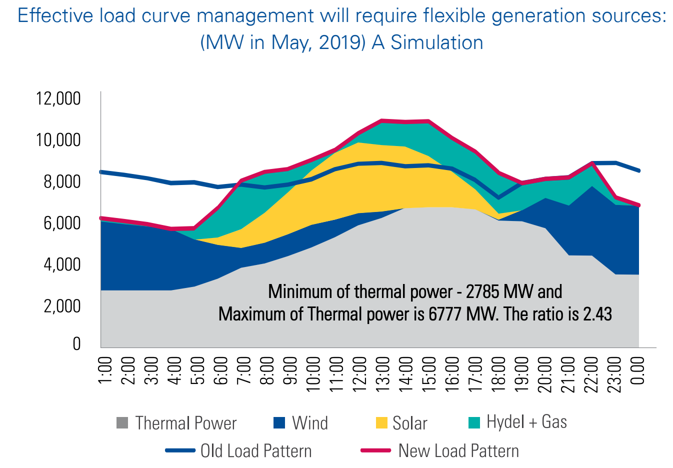
The central government has already announced large solar PV capacity addition(s) through solar parks of around 17,418 MW across 20 states.[14]

**Phase 2 ('Uncomfortable' phase): Utilities that feel the pain of rising solar levels may begin to resist (2017-2020, cumulative 50-60 GW)**

This happens when solar penetration levels reach a threshold, when it begins to seriously affect dispatch of conventional generators. This could be especially so in states with a high installed capacity of wind power as well. In states which are rich in wind and solar potential, the PLFs of conventional generators may fall by as much as 10-15 per cent. The fall in PLF and the ramp rates required are illustrated by the following figures. Analysis has been done for a southern India state with a penetration level of 25 per cent of solar and wind.

The residual load curve (load curve after considering generation from the must run renewable energy sources) profile demonstrates large ramp-up and ramp-down requirements. Further, the residual load curve is typically subject to seasonal variation and is influenced by weather conditions. This puts additional pressure on base load stations and requires them to become more flexible.

Figure 19: Estimated load curve – Illustration for a southern state of India




Source: KPMG in India's analysis, October 2015

The challenges arising from the increasing penetration of intermittent energy sources can be mitigated to an extent by the presence of flexible loads such as agriculture water pumps. This also presents a case to start with very sharp time-of-day tariff, signaling consumers to shift their demands to address supply side constraints.

On the other hand, the commercial aspect of the problem could arise due to the economic impact to conventional generators as their PLFs begin to fall. This could begin to hurt their profitability, and hence there would be resistance. The lower utilisation of conventional coal-based plants could result in an increase in costs and more importantly needs to be factored in today, while going ahead with fresh investments.

[14] Guidelines for Development of Solar Parks Government of India Ministry of New & Renewable Energy October, 2015

**Phase 3 ('Disruptive' phase): Utilities may feel severe pain as solar power is disruptive (storage economics emerges to make a significant dent into grid dependence, 2020 onwards)**

- This happens when the following condition arises: solar power becomes significantly cheaper than conventional power, and penetration levels rise substantially. Storage technologies evolve and become commonplace. The following effects could be seen:
  - Utilities with long-term power contracts feel the pain of stranded contracts
  - Distributed generation picks up substantially as the economics of the 'Solar House' begins to emerge. This leads to some stranding of transmission assets of the utilities.

Utilities may resist and try to impose regulatory costs to recover costs of stranded assets and contracts. As customers begin to increase their share of supply from distributed solar rooftop, the costs of network assets and centralised generation needs to be recovered from the remaining customers which will in turn cause more customers to switch. Grids will need to have tremendous resilience to accommodate very large amounts of solar. However, the evolution of storage technologies will come to the rescue.

According to The Economist article in October, 2013, 'How to lose half a trillion euros - Europe's electricity providers face an existential threat', on Europe's electricity providers, the decline of Europe's utilities has certainly been startling and since September 2008, utilities have been the worst-performing sector in the Morgan Stanley index of global share prices.

The rising share of renewable energy generation across Europe has necessitated a shift in the traditional business models by the utilities.

MSCI European utilities, share price, USD terms - Jan 2005-100


Source: The Economist, Thomson Reuters

# If solar energy is going to be disruptive, will it be advantageous?

The suggestion of disruption raises the question whether aggressively promoting solar energy is of advantage for India. When disruptions sustain, they typically do so for an underlying good. Airplanes disrupted ocean travel, mobile phones disrupted landlines and now e-commerce is disrupting traditional businesses.

In the case of solar power technology, we see solar power disrupting the traditional utility model having large amounts of centralised generation. This disruption can potentially benefit in the following ways:

- On the one hand, it is a clean form of energy and is expected to eventually displace coal over a period of time. This will help in climate change control for a country like India. In many ways, it leapfrogs technology advancements to produce the power that India needs.
- It will help protect our environment and forests as much of our future coal will likely come from under forest land.
- The quality of our distribution grids leaves much to be desired, especially in our rural areas. Direct-to-home power through solar rooftop and storage will help bypass poor quality grids.
- Evolution of storage technologies could lead to the advent of electric vehicles and with that a mitigation of oil consumption. This could eventually help increase India's energy self-reliance and create significant foreign exchange for the country. From a global perspective, it will help increase energy security for many nations and hopefully will resolve or mitigate many wars fought over natural resources.

# The technology spillover effects

Often in the history of technology evolution, we have seen how different domains of technology have complemented and fuelled each other's growth. We see a similar development in respect of solar PV, storage technologies and electric vehicles (EVs). The rise of PV will necessitate evolution in storage technologies and this in turn would support the growth of EVs. These technologies will get integrated through smart grids which will help manage the dynamic nature of generation and loads.

The rise of EVs is likely to be disruptive for the automotive and the oil industry. In the coming decade, we are set to see the technology spillover resulting in PV technology, battery storage and electric vehicles (EV) all becoming mainstay in our energy ecosystem. They will all complement each other. We call this the solar-storage-EV triad.

# Implications for different stakeholders

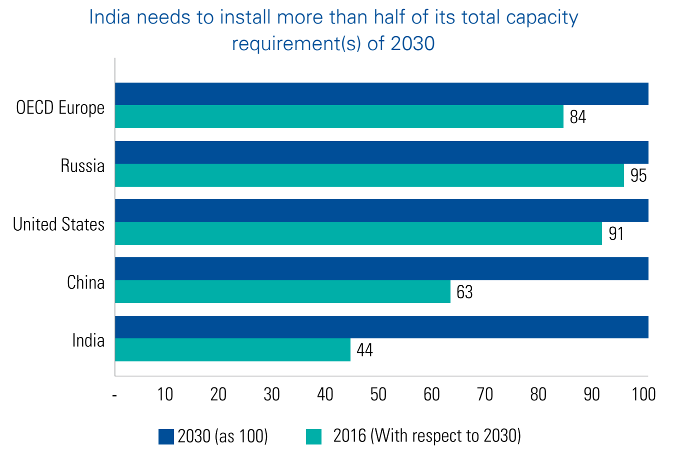
In the preceding sections, we saw how solar power is likely to play a major role in our energy system in the coming decade and beyond. In many ways, it has reached a stage where its forward march is self-sustaining and can increasingly gather more momentum. Different stakeholders need to analyse its impact and prepare for a solar rich future. In this section, we analyse what these actions could be.

## Preparing for the future: The role of the government

### India needs a different planning paradigm

For India, solar power represents a leap-frogging opportunity. This is very unlike the situation in OECD economies or even China. From an overall installed capacity perspective, the installed capacity in 2030 is expected to increase to more than twice that of 2015. A commensurate increase is needed in the transmission and distribution network base.

Figure 20: Installed power capacity comparison - India has a leapfrogging opportunity




Source: 'Energy and Climate Change' - World Energy Outlook Special Report by IEA in 2015, KPMG in India's analysis, October 2015

This special situation will help India to design the right pathway to meet our future energy needs, without running the risk of stranding our current stock of generation or T&D assets. The planning paradigm should consider the following:

- High proportion of variable renewable generation in the grid [scenarios for 20-30 per cent penetration in energy mix should be factored.
- High penetration of distributed generation through rooftops and supported by storage solutions. In general, generation and consumption are likely to be in far greater proximity than today. This should help reduce grid costs for India.
- The rise of technologies such as interactive grids, demand response and different types of storage options.

There is a need to fundamentally rethink our planning processes and approach in order to successfully incorporate a high RE scenario. The added complexity in our country is likely due to the duality of center-state role in planning. Different states are currently planning their own energy mix for the future. A much stronger co-ordination is needed and this can be achieved through a powerful planning entity that is equipped with the right resources. Planning protocols need to be defined which identify the roles and responsibilities of the central planning body and the state bodies.

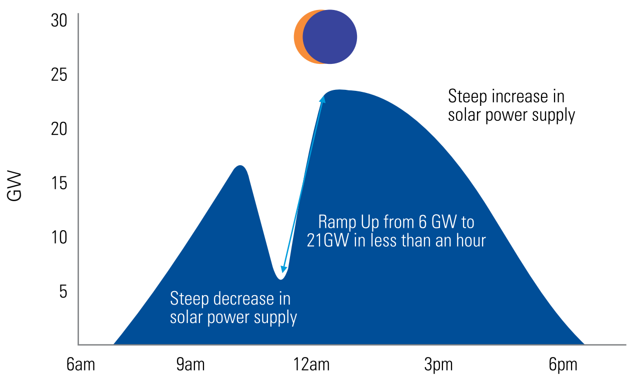
It becomes important to have capacity from different resources such as flexible coal, storage hydro generation, and gas based generation in addition to other technical solutions for grid stabilisation. Such solutions can be developed at a regional level as shared resources. This would have to be complemented by transmission investments. These activities should be initiated early so that we do not have to react after problems occur a few years later.

The successful grid management by Germany during the solar eclipse on 20 March 2015 provides a glimpse of how with a well prepared and planned system, a high penetration of intermittent energy resources can be accommodated.[15] The grid was able to accommodate a ramp-up of 15 GW in one hour (see graph on next page).

A combination of resources with flexible generation capabilities and a strong transmission network can help manage the variability in an effective manner.

[15] http://www.eex-transparency.com/homepage/power/germany/production/usage/actual-solar-power-generation

Figure 21: Impact of the solar eclipse in Germany on 20 March 2015




Source: The German energiewende story-2015

A framework for demand-response solutions, wherein large customers contribute to grid management by shifting their demand patterns, also needs to be initiated.

**Provide budgets for R&D relevant to the Indian context**

One of the biggest beneficiaries of R&D in areas of storage and grid integration is expected to be India. The government should provide budgets to research institutions such as IITs for this purpose. The government could also fund private research in these areas, on the lines of similar programs adopted by the U.S. Department of Energy. The government could declare a research goal such as 'Achieving a bulk storage cost of under INR 5/ kWh by 2020'.

**Develop a framework for ancillary services such as balancing and storage.**

India urgently needs to develop a framework to bring in investment in ancillary services for grid management. Currently, there is no such framework. Such a framework will also help in arriving at the right pricing for such services and thus encourage new investment, vendors and R&D into this area.

**Transmission will be important to address rising land costs**

Currently, land prices for solar power projects range from INR3-7 lakhs/acre[16], but this is expected to increase in the long-term as solar energy scales up and land areas with high solar generation potential near electric sub-stations get used up. While land prices constitutes around 3-4 per cent of the overall solar project cost today, this scenario might change in the future as solar equipment costs keep declining and land prices keep increasing. Assuming that other costs fall by another 50 per cent over the next 10 years and land cost increase to twice current levels, land prices will constitute up to 15 per cent of the overall project cost and in some states could reach 20 per cent. It might become more cost effective in the future to build solar power plants in far-off barren areas as the benefit of cheap land would offset the cost of building additional transmission infrastructure. The graph below illustrates the tradeoff between higher land costs near an electricity sub-station and the cost of building transmission infrastructure to the sub-station.

Figure 22: Transmission investments needed to optimise the land-transmission combo


Source: KPMG in India's analysis, October 2015

Expansion of the transmission network can unlock the sunshine potential of distant and unused lands. This could also keep a check on the rising land prices with more grid connected areas for solar installations being available.

[16] KPMG in India analysis 2015

# Possible implications for power utilities

For power utilities, the implications are significant. Solar power is likely to cause significant disruption to their business models.

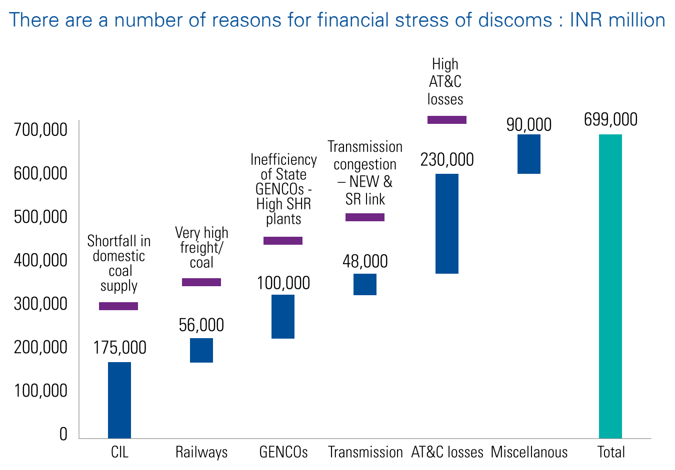
### Finally, competition arrives to traditional utilities

Until now, power discoms operated as monopolies. The pressure to improve efficiency was typically driven by government pressures and not inherent competition. This could change. Decentralised rooftop solar combined with storage will likely present a true threat to the utilities' monopoly. To start with, it may limit the ability of discoms to continuously increase tariffs and cross-subsidies, as consumers switch to alternative solar rooftop supply. As this limits the ability to raise tariffs for certain consumers, it will equally put pressure on the costs of the discoms. As consumers switch, discoms will have no option but to undertake drastic measures to enhance efficiencies and reduce costs.

Apart from the efficiency impact due to Aggregate Technical & Commercial (AT&C) losses, discoms would have to seriously look at their power procurement portfolio and how they are contracting for incremental capacities. The cost structure of new capacities should be closely scrutinised before commitments are made. We find this level of rigour currently lacking, especially for capacities created by state gencos.

### Efficiency levers for utilities

Figure 23: Loss breakup of power distribution companies - FY 12-13 in INR million




Source: Annual Report on The Working of State power Utilities & Electricity Departments 2013-14, Planning Commission, Government of India, PFC Report on Performance Distribution Sector, KPMG in India's analysis, October 2015

As the diagram above shows, the cause of the discom losses is multi-fold and it would require interventions by all stakeholders for it to be addressed. There is a role for both central and state governments in this process.

### Discoms should consider entering the utility driven solar rooftop programme

Discoms should consider entering the distributed rooftop segment themselves. This way they would be at least able to retain their customers and add new revenue streams to their business. Besides, adoption of smart grid and distributed storage technologies would be an imperative in the new age of energy.

Discoms should set aside the right management resources to analyse the developments and options before them.

# The coal sector

As we discussed earlier, the coal sector could face significant pricing pressures in the coming years. The largest coal producer, Coal India (CIL)[17], may face pressure due to falling prices of solar power and its implications for affordability of coal. As we have analysed earlier in the report, post 2022, coal prices would have to begin to chase solar prices and not vice versa as we see today. This shows the importance of following a cost efficient expansion frontier as CIL scales up its production. Apart from solar, various other factors such as slowing growth in China, emergence of energy efficiency on the demand side and fall in the commodities cycle, could lead to pressures on imported coal prices as well. This in turn could put pressure on CIL's costs, as many users may find imports cheaper.

CIL should undertake a detailed study to address costs in the long run and also to bring flexibility in its operations to adjust to different scenarios of demand and costs when the need arises.

[17] https://www.coalindia.in/en-us/company/aboutus.aspx

# Possible implications for conventional generators

India will need to add significant conventional generation capacities to meet its growing demand needs. In fact, as per our base scenario, solar is expected to contribute between 20-25 per cent of incremental energy needs during the next ten years. Considering another 15 per cent could come from wind, it would still imply that about 60 per cent needs to come from conventional energy sources. However, these additional capacities will need different attributes from the ones seen so far such as: 1) flexibility in generation (in terms of ramp rates and minimum thresholds) and, 2) low fixed costs with higher variable costs would be preferred, rather than vice versa.

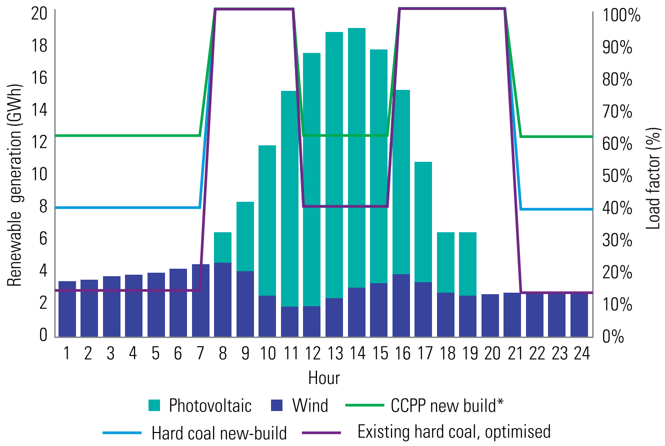
Figure 24: How Germany has adapted its conventional generators to be flexible

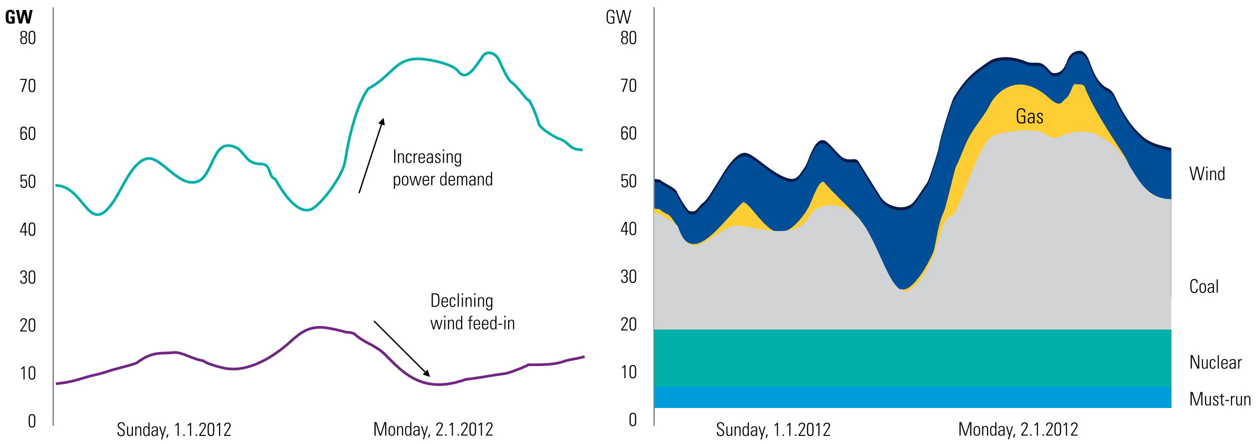
**'German Experience (Schiffer) – Flexible use of conventional power plants for load management'**

In 2014, PV-generated power totaled 35.2 TWh and covered approximately 6.9 per cent of Germany's net electricity consumption.

German power plant operators have made it possible to reduce the minimum load of operation at existing power plants by optimising the boiler-turbine system using modern control systems.

In Germany, the optimised coal-fired power plants are able to operate at a partial-load level of less than 20 per cent of full-load capacity.




Source: CORNERSTONE -'The Flexibility of German Coal-Fired Power Plants Amid Increased Renewables' - By Hans-Wilhelm Schiffer, Executive Chair, World Energy Resources of the World Energy Council, Consultant and Advisor to the Executive Board of RWE AG

For new generators, flexibility should be a necessary criterion. Further, gas and hydro-based generators should be planned strategically to meet the needs of flexibility. A framework for encouraging private investment in these areas is currently absent and this needs to be addressed urgently.

# Possible implications for investors

The economics of solar power clearly represent a large opportunity for new investors. Currently, the field of play appears to be very competitive and new lows are discovered in each round of bidding. This is encouraging for the sector, but at the same time, there appears to be no clear set of players consistently emerging as winners in large tenders, reflective of low entry barriers and inadequate basis for differentiation and competition.

Going forward, we see differentiation opportunities arising in the distributed rooftop space. It could be much more difficult to build scale and differentiators through branding, technology and service. Winners of tomorrow will need to have the right business models to expand reach, reduce costs and offer varied value propositions to customers.

Equally on the grid scale, as the pains of high levels of penetration begin to be felt, there will be an emergence of opportunities in ancillary services including storage solutions and demand response. Investors should look to tapping these opportunities.

### Financing needs of the sector

Until now, the sector typically relied upon sponsor equity and conventional lending channels for meeting capital requirements. Moving up the sophistication curve in financing strategies could soon be a survival imperative for industry players. This will be borne out of the need to tap new sources of capital as well as to find value enhancing strategies for protecting and improving returns.

Over the next five years till FY 2020, traditional lending channels such as commercial banks and public financial institutions ('PFIs') will need to support debt requirement to the extent of ~INR2,500 bn for the solar sector alone, aside from meeting demands of the other sectors within power.

The key question here is whether sufficient capital will be available. Availability of bank credit for the power sector would depend upon: 1) growth in overall loan availability for the industry, 2) share of the pie towards the power sector.

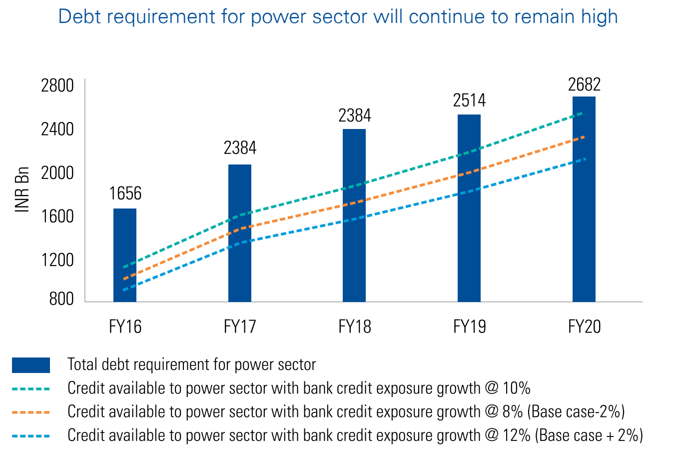
We estimate that:

- Base case growth in gross bank credit to industries will pick up from the recent deceleration seen and will move up to around 10 per cent. We expect an easing of the monetary policy and reducing interest rates to stimulate the credit growth. PFIs focussed on the power sector such as Power Finance Corporation (PFC) and Rural Electricity Corporation (REC) are expected to maintain growth in their loan books at approximately 20 per cent[18].
- We expect the power sector to maintain the current share in industrial credit at ~20 per cent and this level of exposure to power sector is already quite significant.[19] The power sector accounts for the highest share of gross bank credit amongst all industries. Moreover, there seems to be a rising fear of declaration of non –performing assets raising concerns about rate of growth of new credit to the power sector.

[18] Power Finance Corporation (PFC) and Rural Electricity Corporation (REC) Annual Reports 2013-14

[19] Deployment of Gross Bank Credit by Major Sectors, published by RBI - 2012-13, 2013-14, 2014-15

Figure 25: Estimation of credit availability to the power sector and expected demand for debt




Source: KPMG in India analysis, October 2015

As the above analysis shows, renewable energy will need to compete with its conventional cousins for the limited capital available through existing channels. Shortfall in meeting the financing needs of the solar sector is probable, and hence strategies to access alternate pools of capital is now a business imperative. Investors should also develop strategies for:

- Value enhancement: Currently, bank loans are available for the sector at interest rates of around 11 per cent-12 per cent, with a tenure of ~14-16 years (door to door).[20] In an environment of extremely competitive bids, reliance on conventional financing structures will contain Internal Rate of Return (IRR) at ~12-13 per cent. A reduction of 50 bps in interest rate could enhance equity IRRs by more than 0.5 per cent at current tariff levels. Aside from using financing mechanisms such as refinancing or top up loans, strategies to access low cost capital such as international funds and domestic bond markets should be developed at the earliest. Instruments such as corporate green bonds, issue of listed non-convertible debentures to foreign portfolio Investors, or employing short-term financing during construction period such as buyers credit can be explored.
- Monetisation of existing holdings: Sponsors should structure investments in projects in a manner that would facilitate efficient monetisation at a subsequent point in time. Further, advocacy with the government is required to create a favourable environment for platforms such as InVITs -Infrastructure Investment Trusts in India that not only help unlock capital in existing projects but also provide a means for raising fresh capital. In a falling interest rate regime, InVITs investing in low risk business(es) such as solar projects (offering long term yields), are attractive investment opportunities for institutional investors such as insurance/ pension funds.
- Meeting requirements for investment plans in distributed/ off-grid space: Absence of scalable business models and fragmented investor presence have led to lukewarm interest in this space from commercial financiers. Investors will need to focus on developing scalable business models that address the risks perceived by lenders. Players in this segment should explore financing options such as asset finance and channel finance to reduce the constraints imposed by balance sheet financing.
- Skill building: Finally, industry players should plan for financial skill building in their organisations for addressing complexities arising not only out of emerging areas but even within the more 'mature' grid connected ground mounted segment, as projects gain scale and 500-1000 MW sized projects become the new norm.

[20] KPMG in India analysis 2015

# What could prevent the rise of solar energy?

While we have presented a likely scenario of how the solar and power sector will evolve over the next decade, we note below certain factors which could lead to different outcomes from what we have projected. These include:

- **Capital availability:** Solar energy, being capital intensive relative to other conventional sources (capital requirements of INR33 per annual kWh generation compared to INR9 for coal), a scenario where capital availability is challenged due to global economic conditions could hamper the solar march. This scenario would also likely correlate with a deep fall in commodities and prices of fossil fuels like coal and oil. Under this scenario, the achievement of the tipping points for the rise of solar would get delayed.
- **Alternative cheaper carbon efficient solutions:** The other factor that could impact solar energy is the emergence of alternative cheaper forms of energy which are carbon efficient. For example, this could be a sharp rise in shale gas availability globally or a rise in clean coal technologies..
- **Delay in evolution of storage cost curves:** A key element supporting the rise of solar and variable renewables is the evolution of storage technologies. If the pace of storage technology evolution slows down, it could impact the ability of the system to absorb vast amounts of variable renewables. While significant investments are happening in storage technologies, they are at a relatively early stage compared to solar PV or wind and hence there is more uncertainty in their cost trajectories going forward.
- **Unprepared grid infrastructure and utility resistance in India:** From an India perspective, one possible barrier is the ability of our grids to take in large amounts of intermittent generation in the near term. While investments are being made in the transmission infrastructure at the national level, the timely execution of these projects, especially at the state level, is an important factor in ensuring the smooth pace of solar capacity additions. Along with transmission, investments in balancing services and standby capacities are needed. Over the longer term, the disruption to utilities could result in an imposition of regulatory costs on solar and wind and this may slow down their progress.
- **Disruption in Chinese solar manufacturing ecosystem:** Today, China and Taiwan account for over 69 per cent of global module supplies.[21] A hard landing of the Chinese economy, and a scenario where some of the large manufacturers go bankrupt and close down, could hamper global supplies and consequently impact prices of solar panels. In the same scenario, availability of resources for R&D for technological evolution could get hampered and delay further cost reductions.
- **A steep fall in the Indian currency:** Finally, a large part of the solar system cost is import linked. A scenario where the INR depreciates very significantly would lead to a rise in solar costs for India relative to coal. This would delay the rise of solar. For the same reason, it is important for the government to plan a hedge against this scenario by adequately encouraging localisation and the creation of a domestic ecosystem.

The Indian government recognised the promise of solar energy early and rightly gave it the support it needed in its initial days. Along with the central government, various states have also supported it and this has helped to create an initial ecosystem. The solar sector is poised for a rapid scale up and makes an increasing contribution to our energy needs. It is expected to create disruption in the energy sector. As with any disruption, it may create some pain in the short run, but this would eventually lead to a larger good. In 90 minutes, the earth receives as much energy from the sun as mankind consumes in an entire year through fossil fuels. We may be finally close to truly tapping into that potential.

[21] © Fraunhofer ISE: Photovoltaics Report, updated: 20 October 2015

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- Neelima Balachandran
- Nisha Fernandes

**Content Owner:** Santosh Kamath

# Contact us

**Nitin Atroley**
**Partner and Head**
Sales and Markets
**T:** +91 124 307 4887
**E:** nitinatroley@kpmg.com

**Arvind Mahajan**
**Partner and Head**
Infrastructure, Government and Energy
**T:** +91 22 3090 1740
**E:** arvindmahajan@kpmg.com

**Manish Aggarwal**
**Partner and Head**
Energy and Natural Resources
**T:** +91 22 3090 2625
**E:** manishaggarwal@kpmg.com

**Santosh Kamath**
**Partner**
Lead for Renewable Energy
**T:** +91 40 3046 5210
**E:** skamath@kpmg.com

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