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Reaching India's Renewable Energy Targets Cost-Effectively

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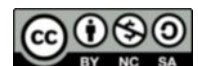
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Executive Summary

India has ambitious targets for renewable energy growth. As part of its Union Budget 2015-2016, India aims to install 60 GW of wind power capacity and 100 GW of solar power capacity by 2022, which is more than six times the current installed capacities of approximately 22GW and 3GW, respectively.

This important task is made difficult by the government's limited budget, which is constrained by a large fiscal deficit and multiple development priorities. Since government support is required when renewable energy is more expensive than the fossil fuel energy it would replace, there is a need for an objective comparison between the levelized costs of electricity from renewable energy and fossil fuels.

This project investigates not only this comparison but also how much it would cost the Government of India to reach its renewable energy targets. We answer this by comparing the levelized cost of electricity from renewable energy to a baseline fossil fuel in absence of any subsidies – whether explicit or implicit;¹ estimating the total cost of support for renewable energy under accelerated depreciation, which is the most cost-effective of existing policies;² and investigating federal policy options to make this support even more cost-effective.

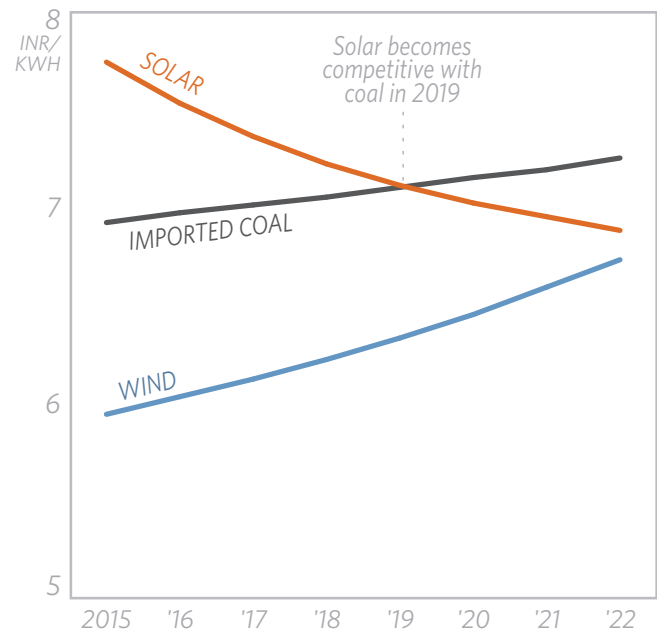
We use the levelized cost of electricity from imported coal as the baseline for this comparison because this is the fuel, rather than domestic coal or natural gas, that renewable energy is likely to replace. While natural gas is the most expensive fossil fuel, it has very limited availability. Imported coal is the next most expensive fossil fuel, and is also projected to account for 18% of India's total generation, higher than India's target of 15% of generation from renewable energy by 2020 (NAPCC, 2008).

Compared to imported coal, the cost of wind power is already competitive, thus requiring no additional support, and the cost of solar power will be competitive by 2019.

We find that wind power is already competitive (see ES Figure 1), meaning the levelized cost of electricity from wind power is the same or lower than that from coal, and would not require any government support. For solar power, the levelized cost of electricity was 11.79% higher than imported coal in 2015.

However, this gap will narrow over time due to learning effects that drive solar capital costs down while fossil fuels become progressively more expensive, primarily due to inflation and increased transportation costs.³ By 2019, solar power is expected to be cheaper than imported coal-based power.

Figure ES 1: Forecast of Levelized Cost of Electricity



1 This is key to ensure that implicit subsidies, such as ones provided to domestic coal, do not distort the comparison.

2 The total cost support includes only system level generation cost and does not account for integration costs as renewable penetration in India is still low (less than 10%).

3 Learning effects are productivity/efficiency gains due to increased experience with a technology, evidenced by an inverse relationship between cumulative capacity and capital cost.

Under current federal policies, the cost of support for meeting India's renewable energy targets is INR 2.71/W.

Since the cost of electricity from wind power is already competitive with fossil fuels, the corresponding cost of government support is zero.⁴ Solar power will continue to require policy support until 2019. Under existing federal policy which allows developers to use accelerated depreciation for renewable energy assets, in today's values, the cost of supporting 20GW of utility scale solar by 2022 is INR 46.97 billion (INR 2.71/W).

The cost of support needed to achieve India's renewable energy targets can be lowered by 96% by using reduced cost, extended tenor debt.

We find that, in place of existing federal policy, a combination of reduced cost and extended tenor debt, where the government provides debt at lower cost and higher tenor than markets, can lower the cost of support

by over 96% to INR 0.1/W. Reduced cost, extended tenor debt also has the advantage of enabling the government to recover the cost of support over time through loan repayments, making it possible to reuse this capital to support other projects.

The cost of support can be further reduced by accelerating wind deployment in the near term and gradually ramping up solar deployment.

Since wind power is already competitive with fossil fuels, the government should focus on supporting rapid deployment of capacity in the near term to minimize its cost of support. Solar power will become competitive with fossil fuels in 2019. Therefore, in order to minimize the cost of government support, solar capacity deployment should be scheduled such that a larger part of the deployment target is met after 2019.

⁴ Cost of support is the net present (or today's) value of the sum of federal and state subsidy cash flows and tax losses.

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1. Introduction

India faces serious challenges of climate change and energy security.

India's energy mix is dominated by fossil fuels, with 68% of total power generated from coal (IBEF, 2014). High dependence on imported oil and increasingly, imported coal, large peak power and energy deficits, and high energy intensity all pose serious challenges to climate change and India's energy security.

To overcome these challenges, India has set ambitious renewable energy targets.

Under India's most recent budget, Union Budget 2015-2016, India aims to install 100 GW of solar energy capacity and 60 GW of wind energy capacity by 2022, which is more than six times the current installed capacities of approximately 22GW and 3GW, respectively (MNRE, 2014a).

However, this is a difficult task due to the government's limited budget, which is constrained by a large fiscal deficit and multiple development priorities. Renewable energy would require government financial support if it were more expensive than the energy from fossil fuels it would replace. Since renewable energy is perceived to be more expensive than fossil fuels because fossil fuels receive implicit and explicit subsidies, there is a need for an objective comparison between the levelized costs of electricity from renewable energy and fossil fuels.

Our objective comparison between the cost of renewable energy and fossil fuels can provide a fair basis for government planning and budget allocation for renewable energy deployment.

In order to estimate the cost of government support needed to achieve India's renewable energy targets, the unsubsidized levelized cost of electricity from renewable energy must be compared with a baseline of the

levelized cost of electricity from the marginal fossil fuel source that it would replace. As we explain in Section 2, renewable energy will likely replace imported coal, so we use imported coal as the baseline comparison.

By forecasting the levelized cost of electricity from renewable energy and from fossil fuels in the absence of any subsidies, we determine the cost of government support required to bridge the difference for renewable energy.⁵ We then identify the most cost-effective policies to achieve India's renewable energy targets.

Over the years, India has put in place several progressive policies, both federal and state, to boost the renewable energy sector. Federal policy support has been in the form of accelerated depreciation, generation based incentive, and viability gap funding, while state policy support has typically been feed-in tariffs.⁶

In our previous work we showed that existing federal policy is not the most cost-effective policy choice for supporting renewable energy (CPI, 2014). Rather, a combination of reduced cost and extended tenor debt, where the government provides debt to renewable energy projects at a lower cost and higher tenor than markets, would be more cost-effective.

In this paper, we build on this work to compare the cost of government support to achieve its renewable energy targets under different policy pathways. The paper is organized in five sections. Section 2 discusses the selection of imported coal as the baseline cost of electricity for comparison with renewable energy. Section 3 forecasts and compares the levelized cost of electricity from renewable energy and the baseline of imported coal. Section 4 examines the cost of government support for renewable energy under different policy pathways. Section 5 presents policy implications.

5 The levelized cost of electricity or LCOE is the minimum per unit revenue required to meet the investors return expectations, given the project's parameters.

6 Each policy is described in Appendix A.

2. Replacing Imported Coal

Renewable energy will likely replace marginal fossil fuel plants, which we use as our baseline for comparing costs.

As India sets out to meet its renewable energy targets, the additional renewable energy capacity will likely replace marginal fossil fuel plants, or in other words the most expensive fossil fuel plants that would have been commissioned in absence of renewable energy deployment. By comparing the levelized cost of electricity from renewable energy with a baseline of the levelized cost of electricity from marginal fossil fuel plants, we can then estimate the cost of government support needed for renewable energy.

Renewable energy will likely replace imported coal-based power.

At present, natural gas is the most expensive source of fossil fuel-based power in India. However, natural gas currently constitutes only 8.6% of the total energy mix due to supply constraints (Ministry of Statistics and Programme Implementation, 2014).⁷ The share of natural gas in India's energy mix has not changed significantly over time. Therefore, natural gas-based power plants are unlikely to be deployed at a significant scale over the next few years, and thus unlikely to be replaced by renewable energy deployment.

On the other hand, the share of imported coal, the next most expensive fossil fuel, as a percentage of total coal consumption has risen steadily from 8.7% in 2006 to 16% in 2012 (MOSPI 2014). Imported coal accounts for 18% of total electricity (CRISIL, 2012), which is higher than India's target of 15% of generation from renewable energy by 2020 (MNRE, 2009). Therefore, imported coal is the most expensive fossil fuel that is likely to be replaced by renewable energy.

We therefore use the cost of electricity from imported coal as our baseline to compare with renewable energy.

Domestic coal remains the predominant source of electricity (CRISIL, 2012), accounting for around 55% of total power generation. However, domestic coal-based power plants will not be the marginal fossil fuel-based plants replaced by renewable energy, since domestic coal is cheaper than imported coal, and the latter already accounts for a larger proportion of total power generation than the proposed share of renewable energy.⁸ However, for reference, we have provided a comparison of domestic coal-based power prices with imported coal based power and renewable sources of coal-based power in Figure 9, Appendix D.

⁷ India's natural gas market is facing a supply deficit due to low domestic production and an inadequate transmission and distribution infrastructure (Ernst & Young, 2014).

⁸ Domestic coal supply is of inferior quality compared to imported coal. However, even after adjusting for heat content, imported coal is more expensive than domestic coal, since government price regulations artificially lower prices.

3. Forecasting the Levelized Cost of Renewable Energy

In order to estimate the cost of government support required to achieve India's renewable energy targets, we begin by forecasting the levelized cost of electricity for three technologies from 2015 to 2022: utility-scale wind and solar power (the dominant renewable energy technologies), and the marginal fossil fuel-based power source, which we determined is imported coal.

The levelized cost of imported coal serves as the baseline cost of electricity. Based on the difference between the forecasted levelized cost of renewable energy and the baseline cost of electricity, we calculate the cost of government support required to meet its renewable energy deployment targets for each year from 2015 to 2022.

Our forecasts for the levelized costs of electricity from renewable energy and imported coal estimate the unsubsidized levelized costs, or the costs without policy support. We estimate the forecasts of the levelized costs for plants commissioned each year from 2015 to 2022 by examining project-level cash flows, which are driven by the variables explained in the following section.⁹

3.1 Drivers of levelized cost of electricity

Several factors, such as return on equity, interest rate, capital expenditure, and the capacity utilization factor, may drive changes in the levelized cost of electricity from renewable energy. By assessing the responsiveness of the levelized costs to these factors,¹⁰ we observe that the levelized costs of both wind and solar energy are highly sensitive to capital expenditure and the capacity utilization factor.

Capital expenditure is the expense associated with acquiring or upgrading property and equipment. In the case of renewable energy projects, this primarily includes turbine (wind) and module (solar) costs, balance of system costs, land costs, construction costs, and evacuation costs. Higher capital costs naturally result in higher levelized costs.

The capacity utilization factor is the fraction of a period of time that a plant is producing energy, and is used as an indicator of plant efficiency. This is the same as another commonly used term – the plant load factor. For example, capacity utilization factors for solar plants without storage are low (around 25%) given that there is typically good sunlight for only six hours out of a 24 hour day; on the other hand, capacity utilization factors for fossil fuel plants can be much higher, around 80-90%. A higher capacity utilization factor typically means higher generation for any given installed capacity and, therefore, lower levelized costs.

Because the levelized cost of electricity from renewable energy sources are most affected by capital expenditure and the capacity utilization factor, these two are the key variables that we forecast to calculate the levelized cost of electricity for solar and wind energy. Other variables have a much lower impact on levelized costs.¹¹

For coal-based power plants (both domestic and imported), the levelized cost of electricity is primarily driven by capital expenditure and fuel cost.

Assumptions in the cash flow model that we use to estimate the levelized costs are available in Appendix B¹² More details on the methodology used for forecasting are in Appendix C.

3.2 Wind power: forecasting the drivers of the levelized cost of electricity

While capital costs are expected to decrease as developers gain experience, capital expenditure for wind energy is expected to increase slightly from 2015 to 2022, due to inflation.

The first key variable that drives the levelized cost of electricity for wind power is capital expenditure, which are the costs associated with acquiring or upgrading property and equipment.

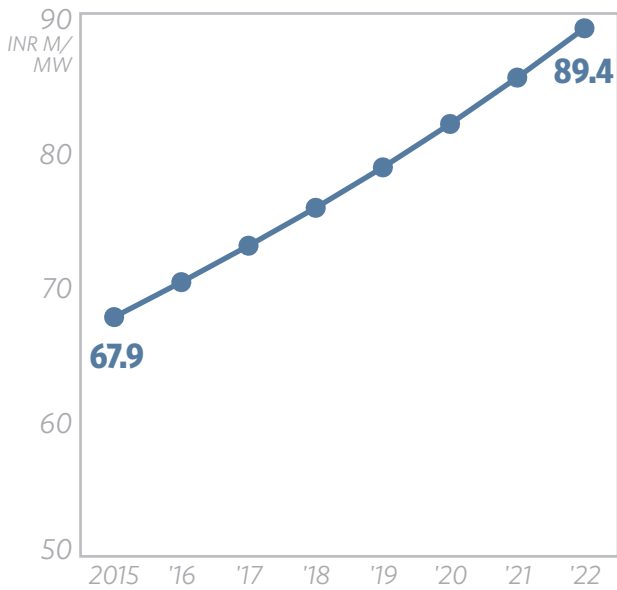
⁹ We provide four possible scenarios for these forecasts, the details of which are in Appendix D. In the main body of the manuscript, we provide analysis based on only the most likely forecasts.

¹⁰ Using sensitivity analysis

¹¹ We have assumed all the other variables such as return on equity, interest rates etc. to remain constant throughout the project life in the cash flow models used to calculate the levelized cost of electricity.

¹² The assumptions (Table 1 in Appendix B) for these models are drawn from a sample of projects from the Bloomberg New Energy Finance (BNEF) database, and validated through the Central Electricity Regulatory Commission's (CERC 2014) benchmark tariffs, as well as our primary research.

Figure 1: Capital Expenditure Forecast for Wind Energy



Our forecasts for capital expenditure for wind power from 2015 to 2022 indicate that it will increase by around 4% each year,¹³ as depicted in Figure 1.¹⁴ The capital cost is expected to rise from INR 67.89 million/MW (USD 1.13 million/MW) in 2015 to INR 89.4 million/MW (USD 1.49 million/MW) in 2022.¹⁵

The primary reason for this is the effect of inflation on component costs. We observe that there will also be a significant reduction in capital expenditure due to a strong learning effect, which is an increase in efficiencies over time as experience with a technology grows. However, the effect of inflation on component costs is much stronger, and outweighs the cost reduction from learning.

The capacity utilization factor for wind power will increase from 25% in 2015 to 29% in 2022.

The capacity utilization factor is the fraction of a period of time that a plant is generating power, and indicates plant efficiency. A higher capacity utilization factor means lower levelized costs.

The capacity utilization factor for a wind plant depends on the height of the turbine from the ground, or hub height, as well as wind speeds. The capacity utilization factor typically increases with hub height due to higher wind speeds at higher elevations. At present, most of

India's wind deployment is at a hub height of 80 meters, with an average capacity utilization of 25%. However, hub heights are steadily rising, with turbines of 100 meters becoming increasingly common (Phadke et al., 2011).

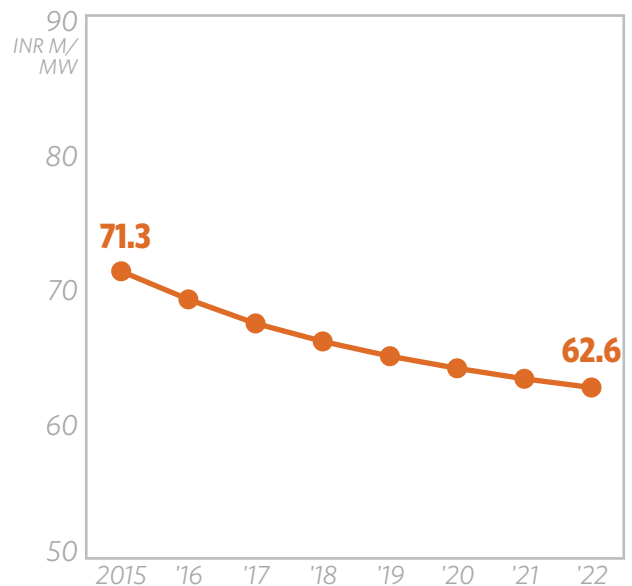
Because of this, we expect that capacity utilization will rise gradually over the coming years. By 2022, we expect that most of the new wind plants will have a hub height of 120 meters, with an average capacity utilization of 29%. This assumes a linear increase in capacity utilization from 25% to 29% based on continued similar wind speeds (Phadke et al., 2011).

Overall, we forecast an increase in the levelized cost of wind energy over time.

An increase in capital expenditure will raise the levelized cost from wind energy, while an increase in capacity utilization factor will lead to a reduction in the levelized cost, but the increase in capital expenditure will outweigh any cost reduction from increased capacity utilization.

3.3 Solar power: forecasting the drivers of the levelized cost of electricity

Figure 2: Capital Expenditure Forecast for Solar Energy



13 4% is the compound annual growth rate (CAGR).
 14 We developed forecasts of capital expenditure for wind power from 2015 to 2022 using four approaches: a) regression analysis; b) trend analysis; c) primary research; and d) literature review.
 15 We assume an exchange rate of INR/USD = 60.

Capital expenditure for solar energy is expected to decline from 2015 to 2022.

We find that capital expenditure for solar power, or the cost of setting up a solar plant, will decrease by approximately 1.83% each year (Figure 2).¹⁶ The capital cost is expected to decrease from INR 71.25 million/MW (USD 1.19 million/MW) in 2015 to INR 62.6 million/MW (USD 1.04 million/MW) in 2022.

This decrease is due to strong global learning effects (increased efficiencies due to experience gained over time), which push down the price of solar panels. We also observe local-level learning effects, which are not as strong, that marginally reduce non-panel costs over time.

The capacity utilization factor for solar energy will remain constant at 20.5%.

The capacity utilization factor indicates the fraction of a period of time that a plant is producing energy. In the case of solar energy, this would depend on the amount of solar resources (solar radiation) as well as the local temperature. Data shows that existing capacity utilization levels are sustainable for the government's proposed solar targets due to abundant solar resource availability.¹⁷ Therefore, it is possible to achieve the government's 2022 solar targets while maintaining the current level of capacity utilization of 20.5% (CERC, 2011).¹⁸

Overall, we forecast that the levelized cost of solar energy will decrease over time.

Since we forecast that the capacity utilization factor will remain constant, the levelized cost of solar energy will be driven downwards by decreasing capital expenditure.

16 We developed forecasts of capital expenditure for solar power from 2015 to 2022 using four approaches: a) regression analysis; b) trend analysis; c) primary research; and d) literature review.
 17 We use estimates for resource availability based on local irradiation and ambient temperature from National Renewable Energy Laboratory (NREL) and National Institute of Solar Energy (NISE). To estimate capacity utilization factors, we use data provided by CERC (2011).
 18 An increase in solar capacity utilization factors would be driven by an improvement in system-level technology, such as use of sunlight tracking devices, which we do not model in this paper.

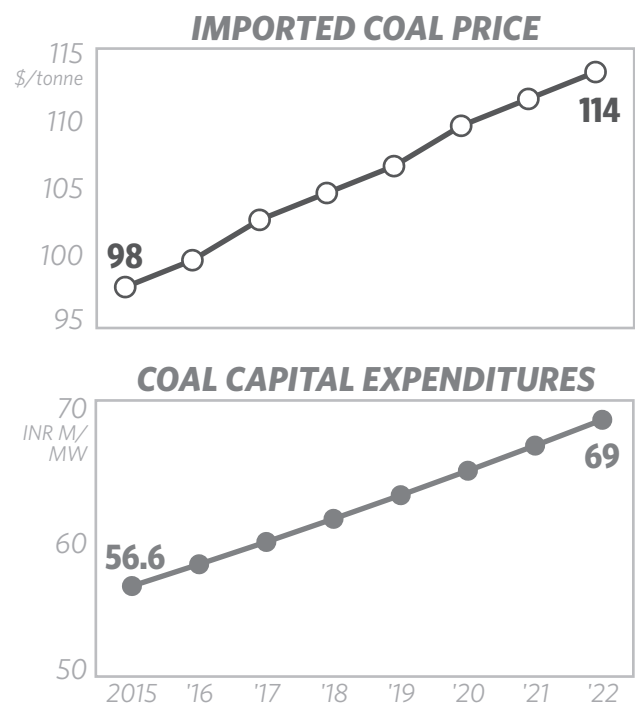
3.4 Imported coal: forecasting the drivers of the levelized cost of electricity

Capital expenditure and coal price are the main variables that drive the levelized cost of electricity for imported coal, so we use those to calculate the levelized cost of electricity from an imported coal-based plant.

Our forecast of capital expenditure for a coal plant shows a steady increase over time (Figure 3).¹⁹ Capital expenditure rises by about 2.86% per year from INR 56.6 million (USD 0.9 million) in 2015 to INR 68.9 million (USD 1.15 million) in 2022.

Forecasts for the second driver, fuel price, indicate an increase of 2.12% each year, from USD 98 per ton in 2015 to USD 114 per ton in 2022 (Figure 3).²⁰ These imported coal prices are driven by global demand and supply.

Figure 3: Capital Expenditure and Fuel Cost Forecasts for Coal Energy



19 Coal capital expenditure forecasts are based on a regression model with inflation (Upadhayay et. al. 2014) as the independent variable.
 20 For fuel cost estimates, we use an average of two coal price forecast series: CPI's New Climate Economy forecasts and forecasts from the Institute for Energy, Economics and Financial Analysis (IEEFA 2014)

Therefore, overall, we forecast that the levelized cost of electricity from imported coal increases over time, due to increasing capital expenditure and fuel prices.

However, the rate of increase in fuel prices is significantly lower than the increase in capital expenditure, causing levelized costs to rise gradually over time.

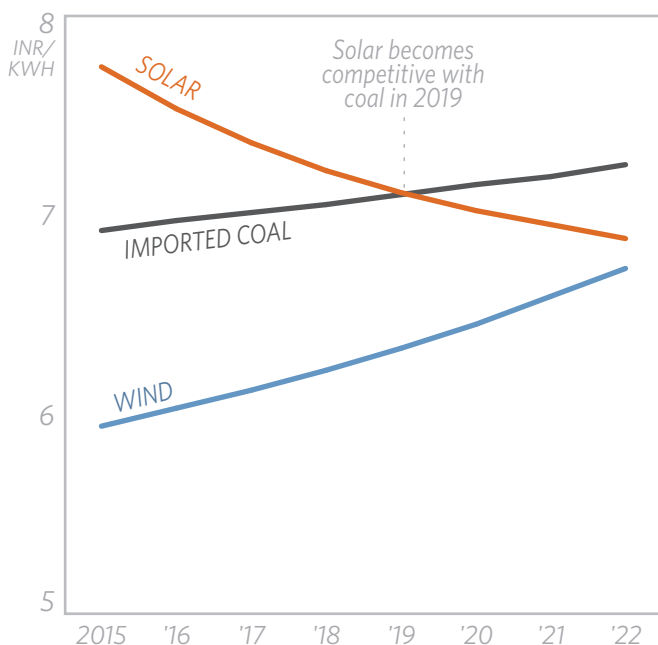
3.5 Comparing the levelized cost of renewable energy with imported coal

By comparing the levelized costs of electricity from wind power and solar power to the levelized cost of electricity from imported coal, which we use as our baseline, we can then estimate the cost of government support required to meet its renewable energy targets.

Wind energy is already cheaper than imported coal based power; but solar plants will require government support up to 2019.

Our analysis shows that compared to the baseline of imported coal-based power, which has a levelized cost of INR 6.92/kWh (USD 0.12/kWh) in 2015, wind energy is already competitive at a levelized cost of INR 5.94/kWh (USD 0.1/kWh).

Figure 4: Forecast of Levelized Cost of Electricity



In spite of the increase in the wind capacity utilization factor, which would decrease the levelized cost of electricity from wind power, we observe an increasing trend in wind levelized costs. The primary reason for this is the increase in capital cost, discussed in Section 3.2, which outweighs the cost reduction from increased capacity utilization.

The levelized cost of imported coal-based power, which serves as our baseline for comparison, is also expected to increase due to an increase in capital expenditure forecasts, as well as rising fuel costs, measured by imported coal prices.

Overall, the gap between the levelized cost of wind power and imported coal-based power is expected to decrease from 14% in 2015 to 7% in 2022. This is primarily because inflation is expected to have a stronger impact on capital expenditure than fuel prices. In the case of wind power, all levelized cost increases are driven by capital expenditure. In the case of coal-based power, since capital expenditure only accounts for a part of the change in the levelized cost, and the increase in fuel price is much more gradual, the overall increase in the levelized cost is not as rapid. However, even though the gap between the costs will grow smaller, wind power will continue to be competitive with imported coal.

Unlike wind energy, solar energy continues to be more expensive than imported coal-based power. The levelized cost of solar energy is INR 7.74/kWh (USD 0.13/kWh) in 2015, about 11.79% more expensive compared to imported coal.

The levelized cost of electricity for solar power declines gradually, driven by the expected reduction in capital expenditure, and becomes competitive with imported coal-based power in 2019 (Figure 4). By 2022, solar energy is expected to become around 5% cheaper than imported coal-based power. The gap between solar energy and wind energy narrows, but solar energy still remains more expensive than wind energy up to 2022 (Figure 4).

Analysis for other possible outcomes is presented in Appendix D.

4. Cost of Government Support

Our forecasts of levelized costs have shown that while wind energy is already competitive, solar energy is still more expensive than imported coal-based power, and thus would require government support. In this section, we present the cost of government support needed to meet India's renewable energy targets. We also identify the most cost-effective policy for providing support. Given that wind energy is already competitive, the cost of support is mainly calculated for solar energy.

The cost of support refers to the required government spending under a policy mechanism to bridge the gap between the unsubsidized levelized cost of renewable power and the baseline cost of electricity. Estimating the cost of support under each policy enables us to identify the most cost-effective policy to support renewable energy.²¹

In India, policy support is provided through a combination of state and federal support. Our previous work (CPI, 2014) found that, in general, any federal support is more cost-effective than state support which is usually in the form of feed-in tariffs.²²

To measure and compare the cost of support, we use the **total cost of support** as our key metric, which indicates the net present value²³ of all the government cash flows over the project life for projects commissioned during 2015 to 2022.²⁴

The cost of support is calculated on the basis of capacity addition of renewable energy for each year and the forecasted difference between the unsubsidized levelized cost of renewable power and the baseline cost of electricity from imported coal.

21 The cost of support is calculated as the sum of federal support, state support and tax reductions.

22 In our previous work (CPI, 2014), we found that 100% support by state-level feed-in tariffs is the least cost-effective policy. We also found that the total cost of support decreases as federal policies cover more of the (viability) gap between the unsubsidized levelized cost of renewable energy and the fossil fuel baseline. Thus, the most cost-effective approach is to meet the entire support requirement through federal policies. Feed-in tariffs may be used in addition to federal support in cases where the difference in levelized cost of renewables and the baseline cost is very high.

23 Net present value is a key financial parameter used to allow comparison of cash flows in different years, by discounting future cash flows to convert them to today's values.

24 We show the total cost of support in absolute terms i.e. INR billion as well as in INR/W terms. INR/W is the ratio of absolute value of the total cost of support to total renewable capacity deployed from 2015 to 2022.

We use the Planning Commission's 12th Five Year plan cumulative capacity targets of 20 GW of solar capacity and 50 GW of wind capacity by 2022. While the Planning Commission has outlined interim cumulative capacity targets at the end of the 12th Five Year Plan (2017) and the 13th Five Year Plan (2022), it does not specify annual capacity addition targets. Therefore, we assume that the annual targets are a linear division of the cumulative targets (Figure 10 in Appendix D).

We use the 12th Five Year Plan targets since the government has created a realistic deployment roadmap for it with interim targets. The Union Budget 2015-2016 targets, on the other hand, were made official very recently in February, 2015 and interim targets are yet to be created. Despite this, based on coarse assumptions, we briefly discuss the implications of the revision in targets in Box 4.1. We note that the results remain similar.

4.1 Total Cost of Support

We examine current federal policies as well as a set of proposed debt-related policies and calculate the cost of government support under each, to determine which is most cost-effective.²⁵ The full list of policies can be found in Appendix A. Among existing federal policies, we give special attention to accelerated depreciation, which is the most cost-effective of current policies.

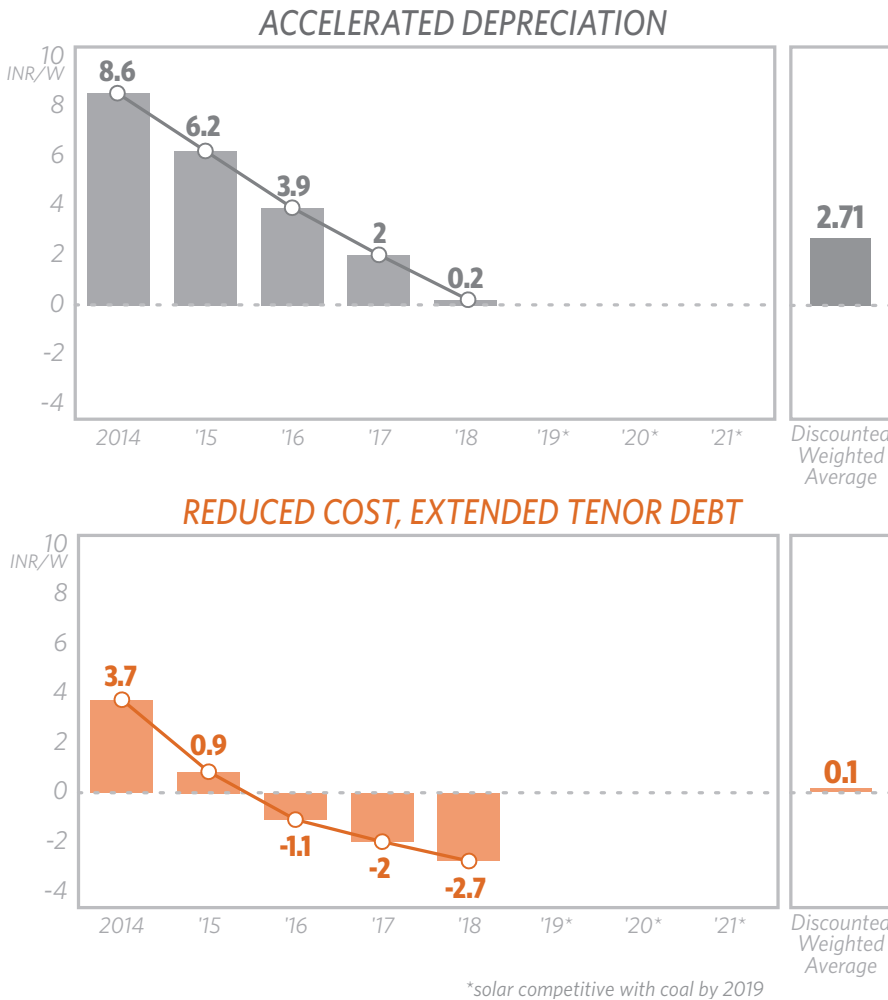
With accelerated depreciation, the most cost-effective among existing policies, the total cost of support for solar is INR 2.71/W.

Accelerated depreciation is a policy which allows the developer to write off the asset value of a renewable energy project in its initial years, thereby reducing tax liability. However, after the value of the asset has completely depreciated, taxes are higher in later years, which would lead to partial government recovery of the cost of support. The government currently provides accelerated depreciation of up to 80% for both wind and solar projects.

As discussed in Section 3.5, wind energy is already competitive, whereas solar energy will require policy support from 2015 to 2019 in order to be competitive with imported coal-based power.

25 Cost-effectiveness is measured by the percentage reduction in total cost of support compared to the baseline, where there is no federal policy support.

Figure 5: Annual Cost of Support (INR/W)



Accelerated depreciation is the most cost-effective policy among the existing federal policies. If the government were to provide policy support through another policy of viability gap funding instead, the total cost of support would be 19% higher.²⁸ In the case of another federal policy called generation based incentive, the total cost of support would be 61% higher compared to accelerated depreciation.²⁹

This is primarily because accelerated depreciation is front-loaded, or in other words, the downward impact on the levelized cost of electricity is higher since the entire benefit of the policy is available to the project developer from the first year, unlike other policies which may spread out the benefits over a longer period of time. Accelerated depreciation also enables the government to recover subsidies, since some of the tax loss is recovered through higher taxes in later years, after the value of the asset is written off completely.³⁰

Under the existing policy of accelerated depreciation, the annual cost of support, defined as the net present value of the cost of support for capacity deployed only in a particular year, declines from INR 8.6/W in 2014 to INR 0.23/W in 2018.²⁶

The corresponding total cost of support, which is the average cost of support over the full project life for plants installed during 2015 to 2018, for solar energy is INR 2.71/W, about 3.8% of the capital cost of solar energy in 2015 (Figure 5).²⁷ Based on the 12th Five Year Plan deployment targets of 20 GW of solar and 50 GW of wind by 2022, the total cost of support is INR 46.97 billion.

However, our previous work shows that it is possible to further lower the total cost of support by using policies that address a key barrier for renewable energy projects – the cost of debt. Inferior terms of debt such as high cost, short tenor, and a variable interest rate add approximately 30% to the total cost of renewable energy in India compared to developed countries (CPI, 2012). Therefore, debt-related policies that address these challenges can significantly reduce the total cost of support (CPI, 2014).

26 Net present value for each year is calculated as of one period prior to the first cash flow. Therefore, for projects starting in 2015, the net present value is calculated for 2014.

27 Since solar energy becomes competitive in 2019, the cost of support is calculated for plants installed prior to 2019.

28 Viability gap funding (VGF) is a capital grant from the government to enable a project developer to supply renewable power at a pre-determined tariff.

29 Generation based incentive (GBI) is a direct subsidy that is paid over and above the tariff for each kWh of power that the developer supplies to the grid.

30 A detailed discussion of the relative cost-effectiveness of different policies is available in CPI, 2014

The total cost of support can be lowered by 96% through policy support in the form of reduced cost, extended tenor debt.

Under a policy of reduced cost, extended tenor debt, the government would make direct loans to project developers below the commercial rate of interest for longer than the usual commercial tenor.

If the government provides policy support through reduced cost, extended tenor debt instead of the existing federal policies, the total cost of support for solar energy can be reduced to an average of INR 0.10/W.

Under reduced cost, extended tenor debt, the annual cost of support varies from INR 3.75/W in 2014 to a recovery (i.e., a profit) of INR 2.73/W by 2018 on account of loan repayments. Based on the 12th Five Year Plan deployment targets of 20 GW of solar and 50 GW of wind by 2022, the total cost of support would be INR 1.81 billion under reduced cost, extended tenor debt, around 96% lower than under accelerated depreciation (Figure 5).

This is because as a policy mechanism, reduced cost, extended tenor debt offers a number of advantages. The net cash outflow for the government is recovered over time since policy support is provided in the form of a loan rather than a grant. It also provides an

opportunity for interest arbitrage: in cases where the government lends at a higher rate of interest to the developer than its own cost of borrowing (7.8% on a 10-year government bond), the net cash flows for the government are positive. Lastly, when debt is cheaper, the developer can substitute equity with more debt in the project while meeting debt servicing conditions. By replacing expensive equity with cheaper debt, the overall cost of capital is reduced.

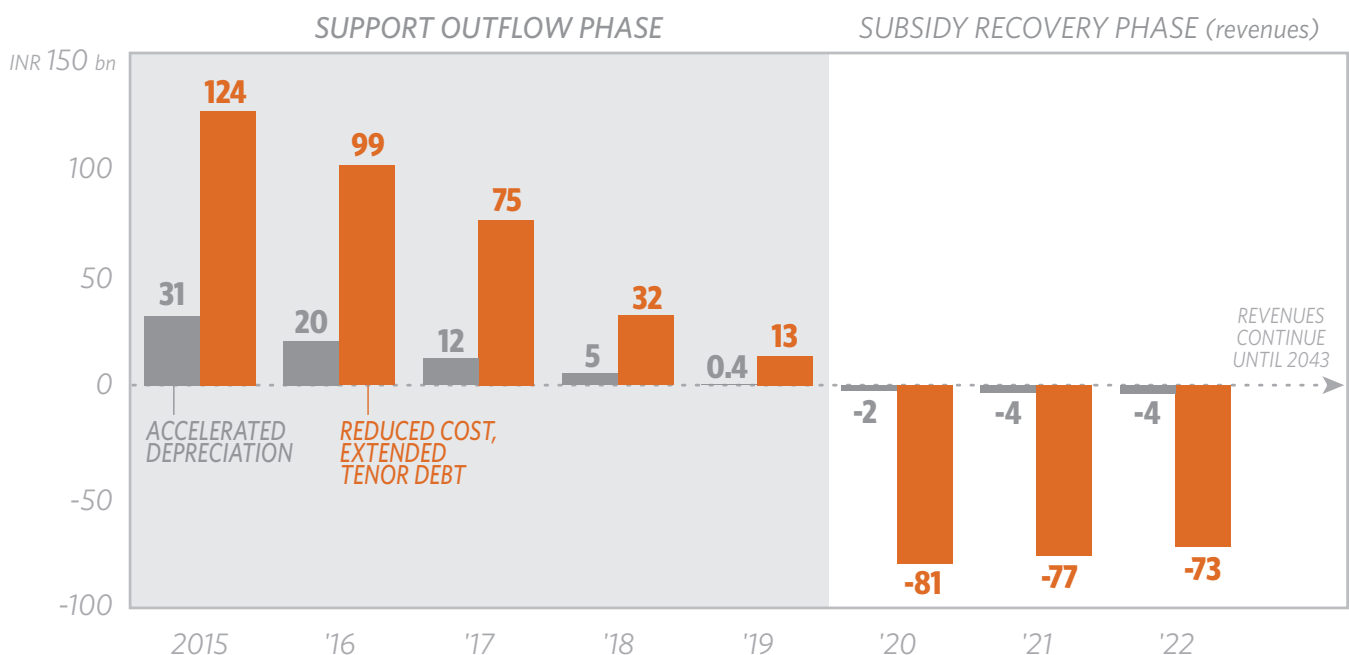
4.2 Nominal Cost of Support

We also look at the nominal cost of support as a measurement of the cost of policy support.

The **nominal cost of support** indicates the net annual cash outflow for the government in nominal terms, i.e. without discounting for time value of money. It is calculated as the sum of net cash outflows for projects deployed in a particular year as well as continuing policy support obligations for projects deployed in previous years starting from 2015.

Whereas the total cost of support includes the effect of future cash flows over a project's life from the provision of a subsidy, the nominal cost of support only measures the net cash outflow for the government at a particular point of time, ignoring any future costs or recoveries for the government. For example, in the case of reduced cost, extended tenor debt, the nominal cost

Figure 6: Nominal Cost of Support for Solar Energy



of support in 2015 will simply be the loan disbursed by the government for the capacity installed in that year, while the total cost of support will account for loan repayments over the entire project life cycle. Therefore, the total cost of support provides a complete measure of the cost of support for the government.

The nominal cost of support, however, is instructive from a budgetary perspective in showing government cash flow profiles for each year. However, it does not facilitate fair comparison of the cost-effectiveness of policies since it does not take into account all the costs over a project's life cycle costs, which is the focus of the total cost of support.

While reduced cost, extended tenor debt is much more cost-effective than accelerated depreciation over a project's life cycle, it would require a higher allocation of the budget in the initial years.

Figure 6 presents the nominal amount required from the government's budget under accelerated depreciation, the most cost-effective among existing policies, and reduced cost, extended tenor debt, which is the most cost-effective among all policy options.

While the net present value, or the total cost of support, for reduced cost, extended tenor debt is significantly lower due to recovery of the subsidy amount invested by the government through loan repayments, the annual budget allocation, or nominal cost of support, for reduced cost, extended tenor debt is much higher in the initial years, since the government needs to provide approximately 70% of the total project cost in the form of debt.

For example, in 2015, based on the 12th Five Year Plan deployment targets of 20 GW of solar and 50 GW of wind by 2022, the total budget allocation for reduced cost, extended tenor debt would be INR 123.79 billion (USD 2.06 billion). In contrast, the nominal cost of support in 2015 under accelerated depreciation is INR 31.2 billion.

However, after 2019, once solar power becomes competitive, there would be a net cash inflow for the government thereafter, since solar power would no longer require additional support, and the policy support provided in the form of debt would be repaid by the project developers. As shown in Figure 6, the

Box 1: 12th Five Year Plan targets vs. Budget 2015 targets

The results presented in this section correspond to the Planning Commission's 12th Five Year Plan targets (from 2011) of 20 GW of solar and 50 GW of wind capacity by 2022. However, our analysis can also be replicated for the government's Budget 2015 targets, which, in February 2015, revised the targets upwards to 100 GW of solar and 60 GW of wind capacity.

Under the Budget 2015 targets, the impact on wind levelized costs (and therefore, total cost of support) is negligible, since the targets are only revised upward by 10 GW. In the case of solar energy, the government's Budget 2015 targets represent a quintupling of the previous targets. Of the 100 GW target, 40 GW is expected to be achieved through utility scale solar and 20 GW through ultra-mega solar, which form the focus of this paper. The remaining 40 GW is to be achieved through rooftop solar.

Based on our model, assuming a linear capacity addition schedule of approximately 7.2 GW per year, we expect that the revision of targets will have a marginal impact on capital expenditure, with the corresponding impact on the levelized cost being less than 4.8%. This indicates that solar energy will become competitive by 2018 and the total cost of support under accelerated depreciation will be INR 1.99/W or INR 113.88 billion. Under the Budget 2015 targets, the total cost of support for solar (Section 4.2) will be roughly 2.5 times the total cost under the 12th Five Year Plan targets.

The revision of targets would also have other implications for deployment paths and grid balancing, which require further examination. Due to these reasons as well as to the lack of concrete roadmaps for these recently announced targets, this paper focuses on the 12th Five Year Plan targets, as indicated earlier.

subsidy recovery is approximately 25 times higher under reduced cost, extended tenor debt as compared to accelerated depreciation.

Therefore, although the government will need to make a budgetary commitment that is four times that of accelerated depreciation in the short term, the net cash outflow in the long term will be 96% lower with reduced cost, extended tenor debt. In other words, in net present value terms, the total cost of support under accelerated depreciation is about 25 times higher than that of reduced cost, extended tenor debt.

The total cost of support can be further reduced if the government accelerates deployment of wind energy in the near term, and gradually ramps up deployment of solar energy.

Our analysis shows that wind energy is already competitive, and so the government's targets for deploying wind energy can be met quickly. The government can encourage rapid deployment of wind energy by creating a friendly policy environment that focuses on other barriers to wind deployment, for example, challenges in land acquisition and delays in environmental clearances (TERI, 2014).

By 2022, we anticipate that solar energy will be cheaper than other sources of electricity. However, at present, solar energy is competitive only in the presence of policy support. Thus, in the absence of direct policy support, it is likely that a larger proportion of solar capacity will be commissioned after 2019, when solar energy becomes competitive.

A schedule of solar capacity addition in which a larger part of the capacity addition takes place after 2019 is tenable for the 12th Five Year Plan targets, and would also minimize the total cost of support for the government.

However, the Budget 2015 targets of 100 GW (see Box 1) may be difficult to achieve if much of the capacity deployment is delayed to 2019. In order to accelerate solar deployment in the near term, the government will need to provide more financial support to solar project developers and should therefore consider the cost implications of changes to the capacity addition schedule.

5. Conclusions

We examine how much it would cost the Government of India to meet its renewable energy targets. By comparing the unsubsidized levelized cost of electricity from wind and solar energy to a baseline of the levelized cost from imported coal-based power, we provide a fair basis upon which the government can plan and allocate its budget to meet its renewable energy targets. We also examine the cost of government support under different policy mechanisms to determine which is most cost-effective, and we examine the implications of different deployment pathways.

Renewable energy will likely replace imported coal based power plants.

Imported coal-based power is playing an increasingly prominent role in India's energy portfolio, accounting for about 18% of total electricity production, a proportion that is steadily rising. India targets 15% of power generation from renewable energy sources by 2020 (NAPCC, 2008), which will replace the most expensive fossil fuel. Since imported coal-based power is more expensive than domestic coal, and the share of natural gas is unlikely to grow due to supply constraints, it is likely that renewable energy will replace additional imported coal build.

Compared to imported coal, wind energy is already competitive, while solar energy will become competitive in 2019.

Compared to imported coal-based power, wind energy is already cheaper, and is expected to remain so up to 2022. Therefore, it would be cheaper to meet additional energy requirements through wind energy rather than imported coal. The levelized cost for solar energy is expected to decline steadily and become cheaper than imported coal by 2019. Due to its continuing decrease in cost, we expect that solar energy will be the most viable source of renewable energy within the next ten years.

Under current policy, the total cost of support for solar energy is INR 2.71/W.

Wind energy does not require government support, since it is already competitive. Under the current federal policy of accelerated depreciation, the most cost-effective among existing policies, the total cost of support for solar energy is about 3.8% of its current capital costs, which is INR 2.71/W under accelerated depreciation. The annual cost of support varies with the levelized cost of solar and imported coal-based power, declining from INR 8.6/W in 2014 to INR 0.23/W in 2018.

The total cost of support for solar energy can be lowered 96% by using reduced cost, extended tenor debt instead of accelerated depreciation; however, this will require a larger amount of support in the initial years.

A combination of reduced cost, extended tenor debt is a more cost-effective policy option than the current policy of accelerated depreciation. Compared to accelerated depreciation, the total cost of support can be lowered by 96% by using reduced cost, extended tenor debt. However, this will require a larger allocation of the government budget for debt in initial years, which will be recovered in later years.

The total cost of support can be further reduced if the government focuses on accelerating deployment of wind energy now, and gradually ramps up deployment of solar energy.

Since wind energy is already competitive with imported coal-based power, it can be deployed very quickly without any policy support. In the case of solar energy, policy support would be more cost-effective if a larger proportion of the deployment targets were met after 2019, when solar energy will be competitive. In order to accelerate solar deployment sooner, the government would need to provide some policy support.

Future Research

Future work will focus on developing analytical frameworks to compare renewable energy and fossil fuels in other ways, including total cost to society (including carbon, resource, integration, etc.), cost of capital (due to different risk profiles), and energy security.

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7. Appendix

A. Financial Support Policies

In this section, we briefly discuss the state policies, existing federal policies, and a new class of debt-related federal policies which are used to support renewable energy.

State Policy

State policy support is typically provided through feed-in-tariffs. A feed-in-tariff is a long-term power purchase agreement of 20-25 years. Under this agreement, the tariff is based on the cost of power production and is higher than the average pooled purchase cost (APPC).³¹

Existing federal policies

In addition to the state-level policies, renewable energy also receives federal level policy support.³² A renewable energy project can avail any one of these federal policies at a time. However, for the purpose of comparison, we calculate the cost of support under all these policies for both wind and solar energy.

- **Accelerated depreciation** allows the developer to write off the asset value in the initial years of the project, thereby reducing the tax liability.³³ However, after the value of the asset has completely depreciated, taxes are higher in later years, which would lead to partial recovery of the cost of support. The government currently provides accelerated depreciation of up to 80% for both wind and solar projects.
- **Generation based incentive (GBI)** is a direct subsidy that is paid over and above the tariff for each kWh of power that the developer supplies to the grid. The support can be availed at INR 0.50/kWh for a minimum of four years and a maximum of ten years with a cap of INR 6.2 million/MW. The objective is to incentivize higher power production. The scheme is available for both wind and solar in parallel to

accelerated depreciation, but on a mutually exclusive basis. While there is no minimum capacity fixed under the scheme for wind projects, solar projects in the range of 100 kW to 2 MW can avail this scheme (PIB, 2011).

- **Viability gap funding** is a capital grant from the government to enable a project developer to supply renewable power at a pre-determined tariff. It was introduced for solar projects under Phase 2, Batch 1 of the National Solar Mission. The government provided a capital subsidy in installments with an upper limit of 30% of the project cost or INR 25 million per MW (PIB, 2014).

Proposed debt-related policies

In our previous work (CPI, 2012), we found that the greatest barrier to renewable energy in India is the inferior terms of debt – i.e., high interest cost, short tenor, and variable rate. We found that the terms of debt raise the cost of renewable energy in India by around 30% compared to similar projects in the US. Hence, in addition to existing policies, we also consider four promising debt-related policies: interest subsidy, reduced cost debt, extended tenor debt, and a combination of reduced cost, extended tenor debt (CPI, 2014).

- **Interest rate subsidy.** Under this policy, the federal government would service a part of the interest obligation of a project, by directly making a partial interest payment to the bank for a commercial loan. This would help reduce the effective rate of interest. Although no such policy currently exists for renewable power generation, the Ministry of Power provided an interest rate subsidy of 3% for 14 years under the National Electricity Fund to public and private power distribution utilities in order to improve their financial health. The government now plans to provide an interest subsidy for renewable energy projects using KfW's grant of EUR 1 billion to IREDA (BridgetoIndia, 2014).
- **Reduced cost debt.** The federal government would directly lend below the commercial rate of interest to renewable projects, either using funds earmarked for the purpose, or by raising money from bond markets and on-lending

31 Average pooled purchase cost (APPC) is the weighted average pooled price at which the power distribution companies purchased electricity in the previous year from all energy suppliers, except renewable energy sources.

32 In addition to these federal policies, projects engaged in the generation (or distribution) of renewable power are eligible for a 10-year tax holiday. Although plants have to pay a minimum alternate tax (MAT) of ~21%, it can be offset in future years.

33 Accelerated depreciation was withdrawn for wind in April, 2012 which led to fall in the investment and the deployment of wind projects but has been reinstated in 2014 again (Business Standard, 2014).

the proceeds. For example, the Brazilian Development Bank's (BNDES) provides low-cost loans for renewable energy projects (IEA, 2012).

- **Extended tenor debt.** The federal government would directly lend to project developers at the commercial rate of interest, but for a longer than commercial tenor. It has been identified as one of the policies desired under the proposed National Wind Mission (MNRE, 2014b).
- **Reduced cost, extended tenor debt.** The government would make direct loans to project developers below the commercial rate of interest for longer than commercial tenor. For

example, under the IREDA-NCEF refinance scheme, the debt of renewable projects can be taken out using concessional finance from IREDA, thereby reducing the effective rate of interest and increasing the tenor of debt.

In the following section, we describe the methodology for computing the cost of support under each of these policies.

B. Assumptions for Cash Flow Models

(See Table 1 below)

Table 1: Assumptions for Cash Flow Models

ASSUMPTIONS	WIND	SOLAR	COAL
POWER GENERATION			
CAPACITY UTILIZATION FACTOR ¹ (P50 PLF)	24.5% FOR THE PROJECTS TO BE COMMISSIONED IN 2015 [#] .	20.5%*	75%*
USEFUL LIFE	25 YEARS	25 YEARS	40 YEARS
CAPITAL COST			
CAPITAL COST (INR MILLION/MW)	BASED ON FORECAST OF SOLAR PLANT CAPITAL COST (SECTION 3.2)	BASED ON FORECAST OF WIND PLANT CAPITAL COST (SECTION 3.3)	BASED ON FORECAST OF COAL PLANT CAPITAL COST (SECTION 3.4)
FINANCIAL ASSUMPTIONS			
MINIMUM DEBT SERVICE COVERAGE RATIO ²	1.3	1.3	NA (FIXED DEBT TO EQUITY RATIO)
P90 PLF ³ (DEBT CONDITION)	22.5% FOR THE PROJECTS TO BE COMMISSIONED IN 2015 [#] .	19%*	NOT APPLICABLE
DEBT			
REPAYMENT PERIOD	12 YEARS	12 YEARS	10 YEARS
INTEREST RATE (FIXED)	12.30%	12.30%	12%
EQUITY			
EXPECTED RETURN ON EQUITY ⁴	17.90%*	17.30%*	15.50%*
TAX INCENTIVE			
TAX HOLIDAY	10 YEARS	10 YEARS	NOT APPLICABLE
MINIMUM ALTERNATIVE TAX	20%	20%	NOT APPLICABLE

1 Capacity utilization factor can be defined as fraction of time that a plant is producing energy.

2 Ratio of cash flows available for debt servicing to interest and principal.

3 P50 PLF or plant load factor represents the most likely output of the plant, while P90 PLF is a conservative estimate of the plant load factor.

4 Return on equity (ROE) is the amount of net income returned as a percentage of shareholders equity.

* We assume that these variables remain constant throughout the project life-cycle of all the projects to be commissioned till 2022.

Increases by 0.5% every year for the projects to be commissioned in subsequent years.

C. Methodology used for forecasting capital expenditure

Solar capital expenditure (capex) consists of module costs and non-module or balance of system costs. The market for PV modules is global. However, non-module costs such as land, labor and transmission costs depend on local or country-level factors. Therefore, it is possible to extrapolate module costs based on global data, but non-module costs have to be estimated using Indian data.

For wind energy, turbine costs constitute 70-85% of the total system cost. The major components of the turbine costs are rotor blades, tower, generator, transformer, power gearbox and power converter. The remaining system costs consists of land cost, grid connection, construction cost, and consulting cost. Due to the lack of granular data, we forecast wind capital expenditure at the system level.

We used four approaches for estimating capital expenditure for wind and solar energy:

1. **Literature Review:** We examine existing solar and wind capex forecasts from secondary sources (Shakti Foundation 2013) and the assumptions underlying these forecasts.
2. **Trend Analysis:** Simple extrapolation of historical capital costs. We extract project level capital cost yearly data from BNEF and other secondary sources and make simple forecasts using trend lines - in this case, we implicitly assume that historical trends will continue for the next seven years.
3. **Regression Analysis:** We identify the key drivers of capital costs for wind plants and solar plants through literature review (Berry, D (2009) for Wind; Nemet, G.F. (2006) & Pillai, U & K. Cruz (2013) for Solar). Using the appropriate regression model, we forecast the capex for wind and solar plants from 2015 to 2022.
4. **Primary Research:** The three methods detailed above provide an estimate of the ranges within which capex estimates lie, and the changes observed with each level of refinement. Based on several interviews of consultants, experts, developers, manufacturer, we drew inferences on expected trends in system costs for wind and solar. Primary research was used to validate the findings of our secondary research, and to obtain insights on expected trends and drivers for solar and wind capex.

D. Results for other scenarios-Sensitivity Analysis

To account for the inherent uncertainty in forecasts, we provide four possible scenarios for cost of support.

We develop three sets of forecasts: best case (i.e. renewable based unsubsidized levelized costs drop rapidly and imported coal based levelized cost rises significantly); worst case (i.e., renewable based unsubsidized levelized costs do not decrease much while the levelized cost of imported coal shows a declining trend); and the average case, which combines all forecasts to arrive at the most likely or the most probabilistic scenario. The best case will represent the minimum cost of support for renewable energy, and in the worst case, the cost of support will be the highest.

We also consider a fourth scenario as an additional case, where the average case unsubsidized levelized costs of renewable power are compared with the levelized cost of domestic coal-based power.

Forecast of unsubsidized levelized cost of electricity

In the best case, levelized costs for wind energy show an increasing trend, while solar energy shows a decreasing trend. Both are cheaper than imported coal-based power.

Figure 7: Forecast of Levelized Cost of Electricity - Best Case

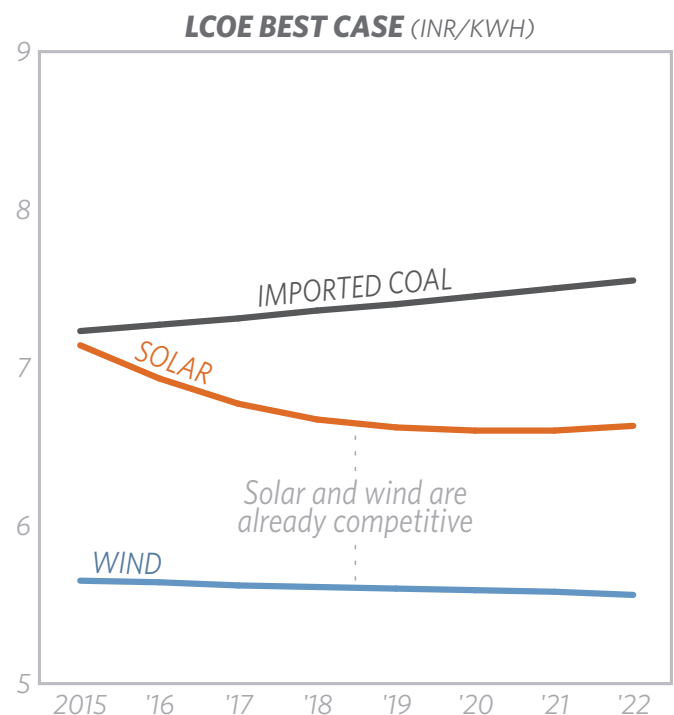
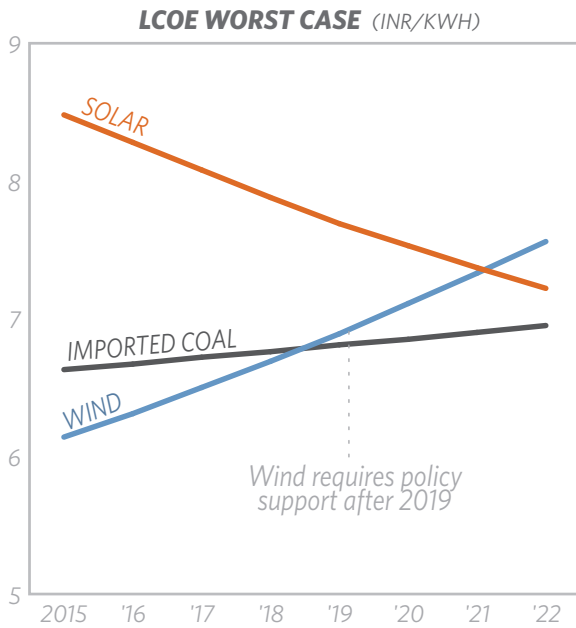


Figure 8: Forecast of Levelized Cost of Electricity - Worst case



In the worst case, wind energy would require policy support after 2019, while solar energy would require policy support up to 2022.

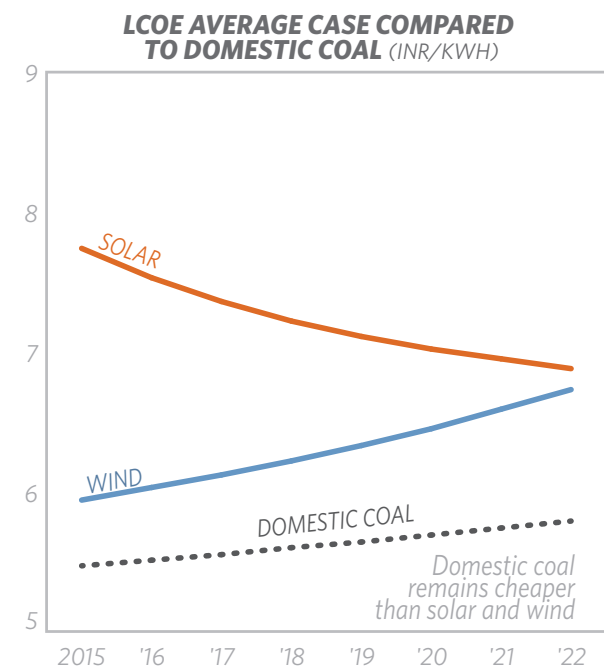
In the worst case (Figure 8), the levelized cost of imported coal rises at a very gradual rate from INR 6.63/kWh in 2015 to INR 6.95/kWh in 2022. On the other hand, wind levelized costs rise rapidly from INR 6.14/kWh in 2015 to INR 7.56/kWh in 2022. The levelized cost of wind is expected to be 7.5% lower than imported coal in 2015 but will become 9% more expensive by 2022. In this case, wind projects will begin to require policy support from 2019 since the effect of inflation on wind is more pronounced.

For solar, the decline in prices is much more gradual relative to the average case, starting at INR 8.48/kWh in 2015 and falling to INR 7.22/kWh in 2022. The levelized cost of solar is 27.9% higher than imported coal, but this gap would reduce to 3.8% by 2022. Hence, solar energy will continue to require policy support until 2022 in order to compete with imported coal-based power.

In the case of domestic coal-based power as the baseline, both wind and solar energy would require policy support throughout 2015 to 2022.

In our additional scenario with domestic coal as the baseline cost of imported coal based power, we find that domestic coal prices are considerably lower than wind, solar and imported coal.

Figure 9: Forecast of Levelized Cost of Electricity - Domestic Coal Case



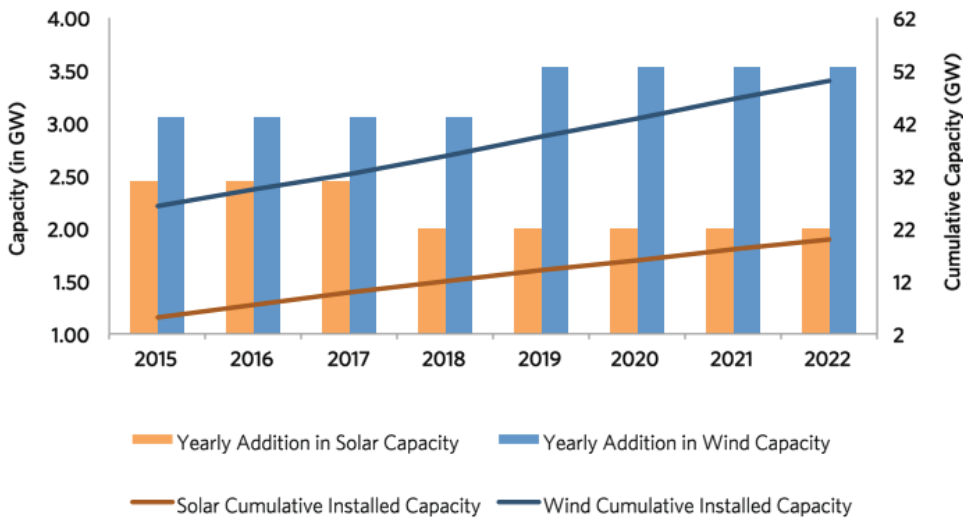
In the best case scenario (Figure 7), we find that wind and solar energy are expected to be cheaper than imported coal-based power.

In 2015, the levelized cost of wind is INR 5.64/kWh and is expected to slowly decline to INR 5.55/kWh by 2022, primarily due to the increase in capacity utilization factor, which outweighs the effect of increasing capital expenditure. The wind levelized cost is currently 22% cheaper than the levelized cost of imported coal, and is expected to become 26% cheaper by 2022.

In the case of solar, the forecasted levelized cost for 2015 is INR 7.13/kWh, and is expected to steadily decline to INR 6.62/kWh by 2022, driven by declining capital expenditure. The levelized cost of imported coal is expected to increase from INR 7.22/kWh in 2015 to INR 7.54/kWh in 2022 on account of inflation and rising fuel prices. The levelized cost of solar energy is expected to be 1.3% cheaper than that of the imported coal based power in 2015.

Therefore, both renewable technologies are already cheaper than imported coal based power in 2015, and do not require any policy support from the government.

Figure 10: Yearly and Cumulative Capacity Deployment Targets of Renewable Energy



solar and wind based power, respectively. As shown in Figure 9, this gap will decrease to 19% in the case of solar energy and increase to 16% in case of wind energy by 2022.

Total Cost of Support - Sensitivity Analysis

Based on the levelized cost estimates discussed above, we estimate the total cost of support in each of the four scenarios. For all scenarios, we assume the capacity addition schedule will follow the path illustrated in Figure 10, constructed on the

The capital expenditure for imported and domestic coal based power plants is the same. Hence, the system level project cost of a coal based plant differs mainly due to the difference in fuel price between domestic coal and imported coal.

Since domestic coal prices are regulated, we use the price of imported coal adjusted downward by 15% for transport, or the import parity price, which indicates the unsubsidized market price of domestic coal (PIB, 2013).

The levelized cost of domestic coal-based power is expected to be at INR 5.47/kWh in 2015. The price increases over time to INR 5.79/kWh in 2022, but remains cheaper than all the other technologies. The levelized cost of domestic coal based electricity is 41.6% and 8.6% cheaper than the levelized cost of

basis of the interim targets declared by the Planning Commission. The total cost of support is zero in the best case since both wind and solar are already competitive with imported coal based power. However, in the worst case, the total cost of support is over four times higher for solar, while wind begins to require policy support.

In the domestic coal case, the total cost of support for solar energy is over seven times higher compared to the support required in the average case with imported coal.

Figure 11 summarizes these results with respect to two policies - accelerated depreciation, the most cost-effective among the existing policies, and reduced cost, extended tenor debt, the most cost-effective of all policies examined in this paper.

Figure 11: Total Cost of Support for Renewable Energy under AD and RCETD

