Decarbonization of Indian Railways

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CPI Introduction

Climate Policy Initiative (CPI) is a team of analysts and advisors that works to improve the **most important energy and land use policies** around the world, with a **particular focus on finance**.

CPI works in places that provide the most potential for policy impact – Brazil, China, Europe, India, Indonesia, and the US.

In India, we focus on the challenges around financing renewable energy, and finding ways to drive more finance to achieve the renewable energy targets.

Decarbonization of Indian Railways could help achieve India's climate goals

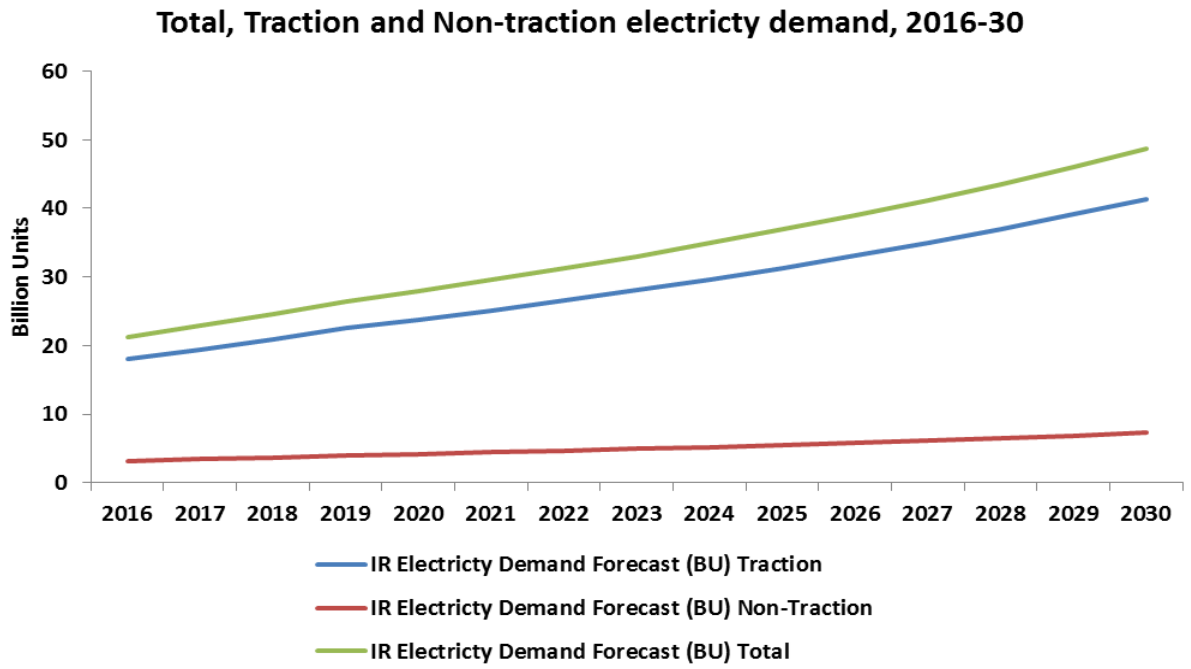
- Paris Agreement Targets for 2030
  - Reduce carbon emissions intensity by 33-35% from 2005 levels
  - Transition to renewable energy for 40% of electricity generation capacity
- IR is the single largest consumer of electricity in India, consuming 2% of total generation
- We identified different potential pathways to decarbonization of IR by 2030 and examined their cost-effectiveness and potential issues around implementation.

Key Questions

1. **How and can IR be decarbonized?**
   - Are there any prerequisites for decarbonization of IR?
   - What are the electricity supply options?
   - What are the decarbonization pathways?
2. **What is the feasibility of various decarbonization pathways?**
   - Commercial feasibility: What are the costs of the various decarbonization pathways?
   - Operational issues: What are the balancing options available?
3. **What are the recommendations for Indian Railways?**

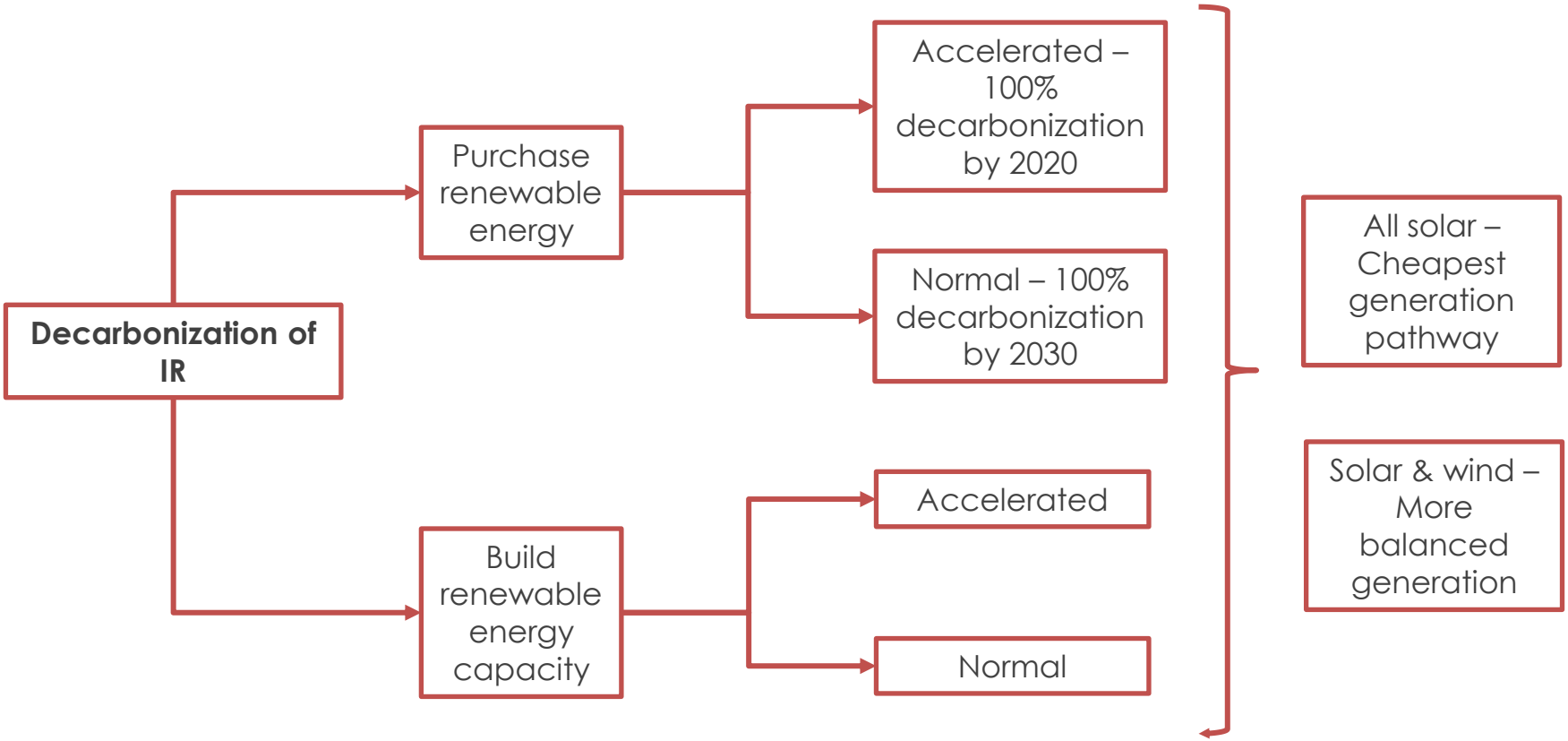
IR's electricity demand will likely grow at a CAGR of 6%, driven by an increase in traffic

- **Total electricity demand will likely grow at a CAGR of 6%** from 18 billion units (BU or TWh) in 2015 to 49 TWh by 2030, which is **nearly three times the current electricity demand.**
- Electricity demand is being driven by increasing electrification and growing passenger and freight traffic.



We assessed commercial feasibility by comparing the pathways with a business-as-usual scenario

- We considered **a decarbonization pathway to be commercially feasible when its costs are lesser than the cost of the business-as-usual (BAU) pathway** currently being followed by IR.
- We examined the different decarbonization pathways to identify the most cost-effective one:

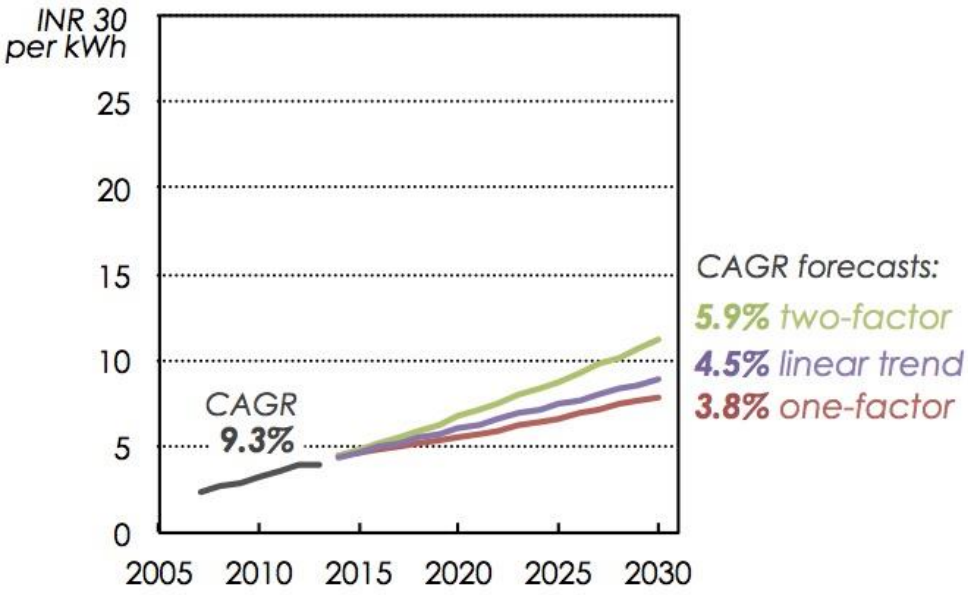


We identified different BAUs for the traction and non-traction segments

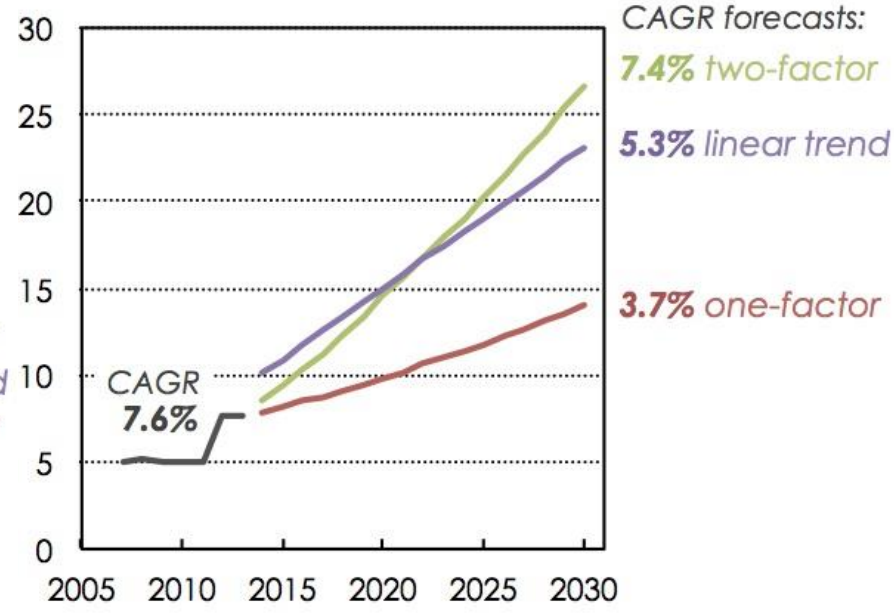
Traction BAU: Average per unit power procurement cost of DISCOMs in India

Non-traction BAU: Average commercial tariffs of DISCOMs in India

Traction BAU scenarios



Non-traction BAU scenarios



Our assumptions for estimating the decarbonization costs

Captive Generation	External Purchases
• 100% owned by IR • Expected return on equity: 14% • Cost of debt: 8.28%; tenor: 12 years • Plant life: 25 years • No land constraint (land costs included) • Mix of wind and solar in the proportion of 47:53 on average	• Electricity purchased from IPPs • Expected return on equity of an IPP: 16% • Cost of debt: 12.76%; tenor: 12 years • All long-term contracts of 25 years

General assumptions:

Landed cost of RE power (LCOP) was considered for estimating the costs of decarbonization pathways. LCOP includes LCOE + T&D charges and losses (not applicable for rooftop) + Cross-subsidy surcharge (applicable for non-traction ground-mounted).

Traction: Accelerated rate captive generation will have highest savings and less variation

- All the decarbonization pathways would be cheaper than the BAU with **savings of 17-32% in average annual cash flows.**
- The most cost-effective decarbonization pathway is captive generation under accelerated rate of decarbonization.
  - The pathway also has less variations in cash outflows.

Savings in Average Annual Cash Outflows compared with BAU, 2016-40

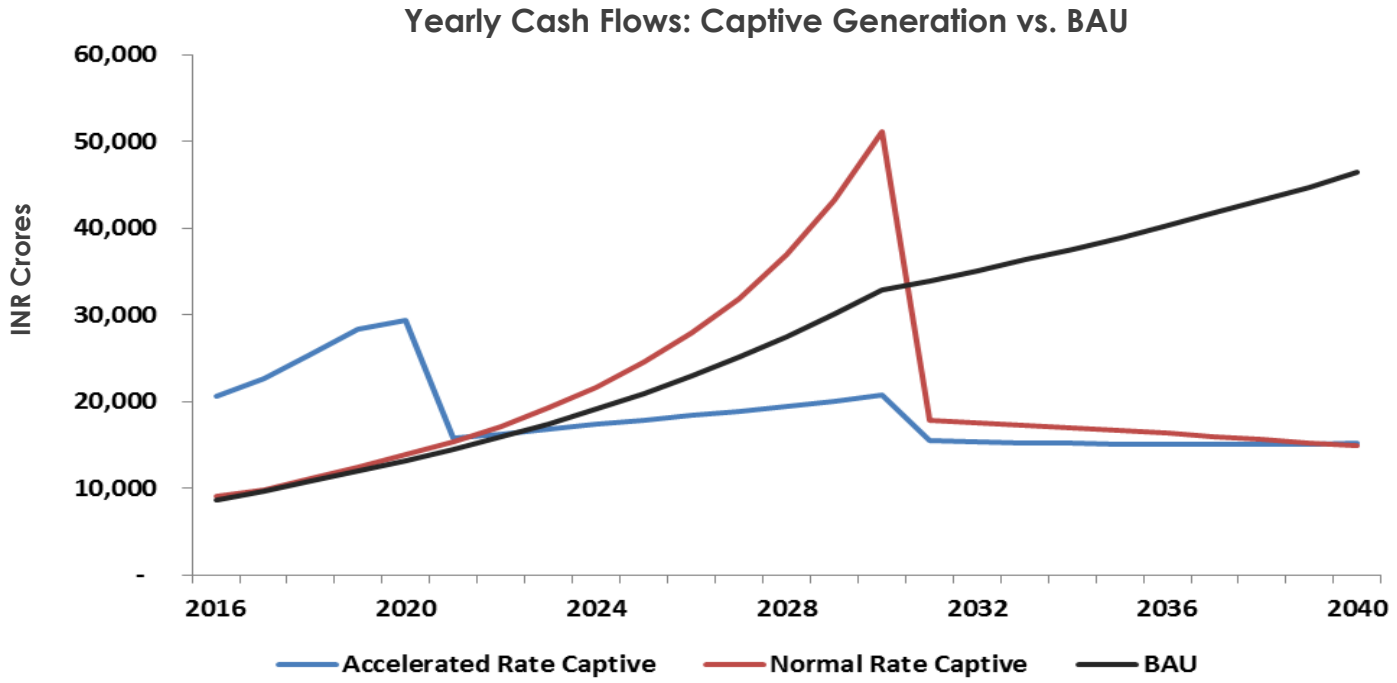
	Accelerated	Normal
Captive Generation	32%	25%
Purchase	17%	24%
BAU	INR 27,145 Crores	

Standard Deviation in Annual Cash Outflows, 2016-40

Figures in INR Crore	Accelerated	Normal
Captive Generation	4,100	10,180
Purchase	5,711	5,836
BAU	12,088	

Traction: Accelerated rate captive generation will have higher spend in the initial years, but larger savings in the long-run

- **In accelerated captive generation**, although IR have to spend 133% more in the initial years (2016-20) compared with the BAU, **in the long run (2016-40) IR will be spending 32% less than the BAU.**
- **In normal rate captive generation**, IR will have to spend 23% more during 2016-30 compared with the BAU, but in the long run (**2016-40**), **IR will be spending 25% less than the BAU.**



Non-Traction: Accelerated rate captive generation will have highest savings and less variation

- All the decarbonization pathways would be cheaper than the BAU with **savings of 40-61% in average annual cash flows.**
- The most cost-effective decarbonization pathway is captive generation under accelerated rate of decarbonization.
- Savings from decarbonization are much higher in the non-traction segment largely due to inclusion of cross-subsidy charges in the DISCOM tariffs.

Savings in Average Annual Cash Flows compared with BAU, 2016-40

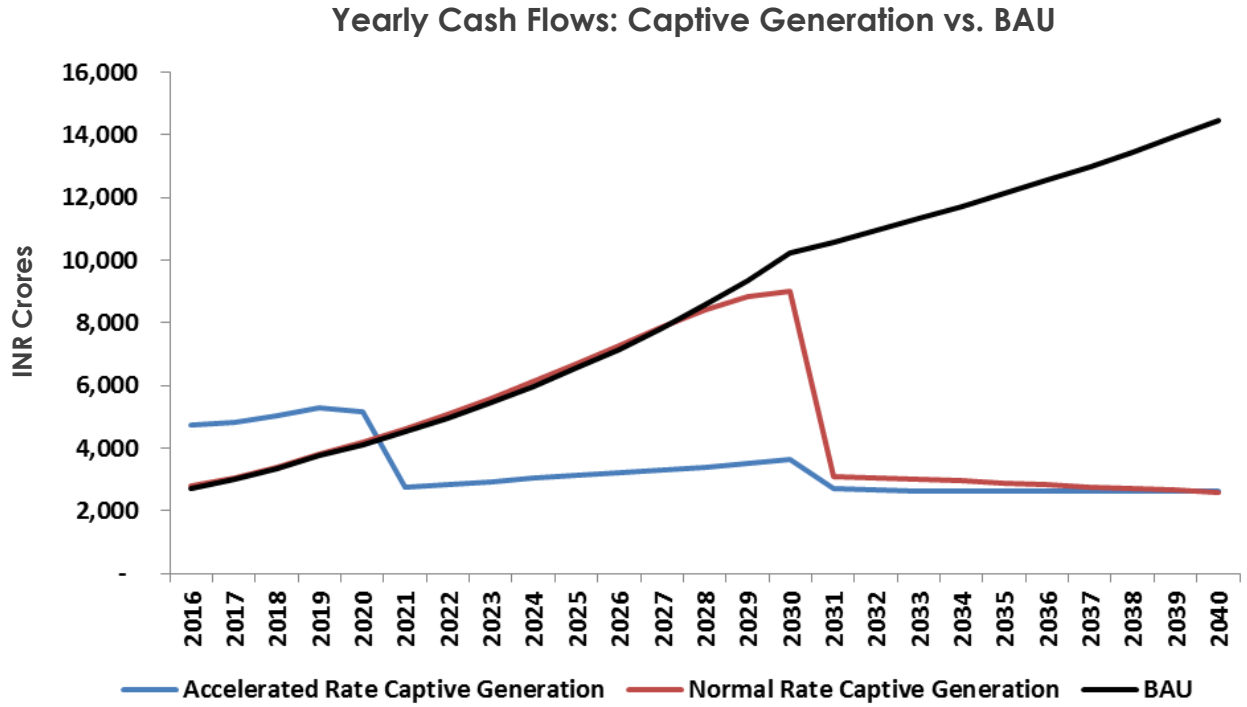
	Accelerated	Normal
Captive Generation	61%	46%
Purchase	45%	40%
BAU	INR 8,470 crores	

Standard Deviation in Annual Cash Flows, 2016-40

Figures in INR Crore	Accelerated	Normal
Captive Generation	897	2,154
Purchase	1,017	1,018
BAU	3,762	

Non-traction: Accelerated rate captive generation will result in lesser cash outflows in the long-run

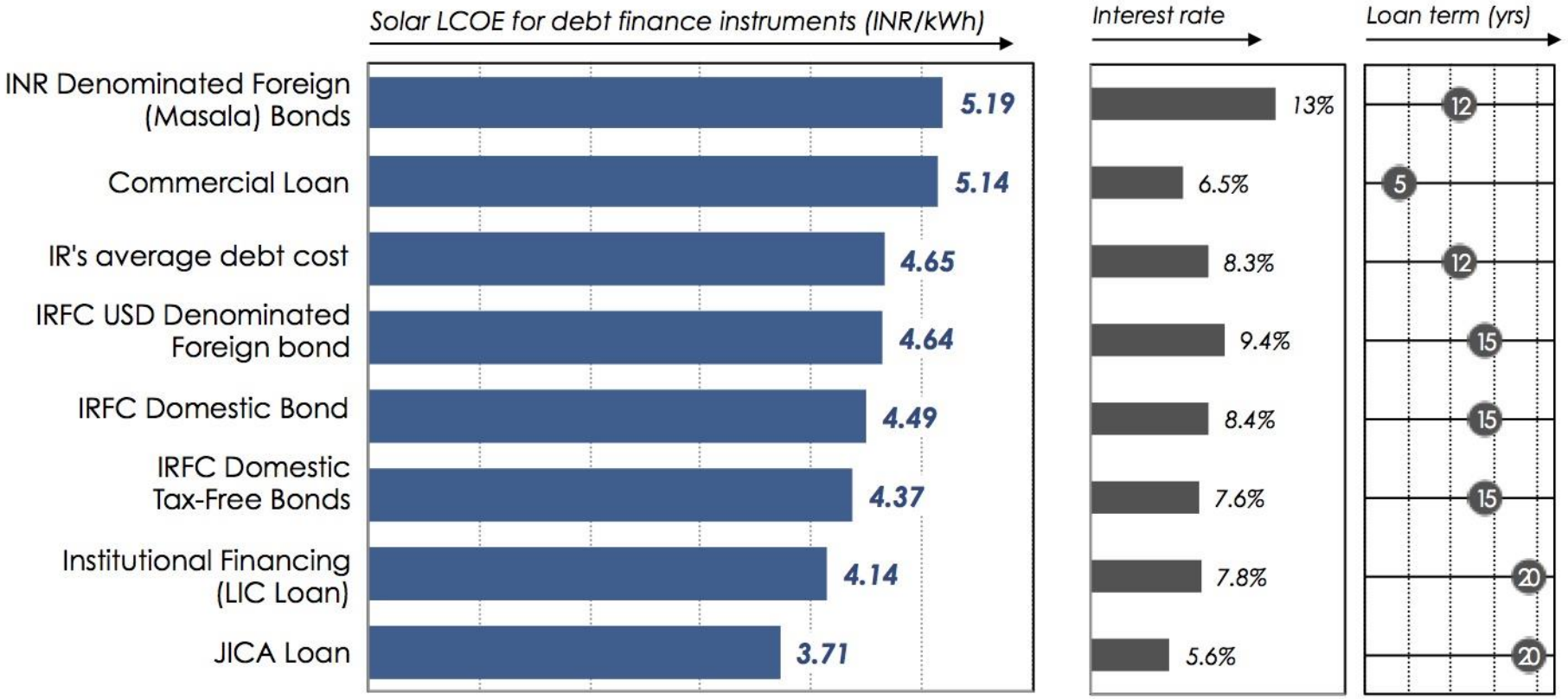
- **In accelerated captive generation**, although IR will have to spend 48% more in the initial years (2016-20) compared with the BAU, **in the long run (2016-40) IR will be spending 61% less than the BAU.**
- **In normal rate captive generation**, IR will have to spend almost the same money as BAU during 2016-30. **However, in the long run 2016-40, IR will be spending 46% less than the BAU.**
- The difference between accelerated and normal rate is largely due to an additional spending of INR 53,340 on conventional power in the latter.



Unconventional financing could lower the cost of decarbonization

IR could reduce the current financing costs further. For e.g., using a JICA loan at 5.6% (including currency hedge), IR could reduce its cost by 20% compared with typical IRFC bond and LIC loan (@8.28%).

Financing Instruments and Impact on Solar LCOE



Balancing: Power banking and pumped hydro are the immediate balancing options available

The most feasible immediate options are power banking and net metering with state DISCOMS. In the next five years, additional feasible options will be flexible thermal power plants, grid-scale battery storage, and trading on power exchanges.

Feasibility →

Flexibility Options ↓

	Low	Medium	High
Demand Response	Load shedding; Load shifting		
Flexible Supply		Flexible thermal power plants	Renewable energy forecasting
Energy Storage		Li-ion battery; Sodium-sulfur	Pumped hydro
Grid Interaction	Trading on power exchanges	Net metering with state DISCOMs	Power banking with DISCOMs

High = available for immediate deployment; Medium = would likely be feasible in 5 years; Low = would like be feasible in the long run (>5 years)

Recommendations

- **For both traction and non-traction segments**, decarbonization through captive generation at accelerated rate will be the most cost-effective pathway
- IR can keep the balancing costs low by exploring low-cost balancing options such as power banking and net metering with state DISCOMs.
- To increase feasibility of implementation, IR should first focus on entering into net metering and open access arrangements in states that have already implemented these policies successfully.

Thank you!

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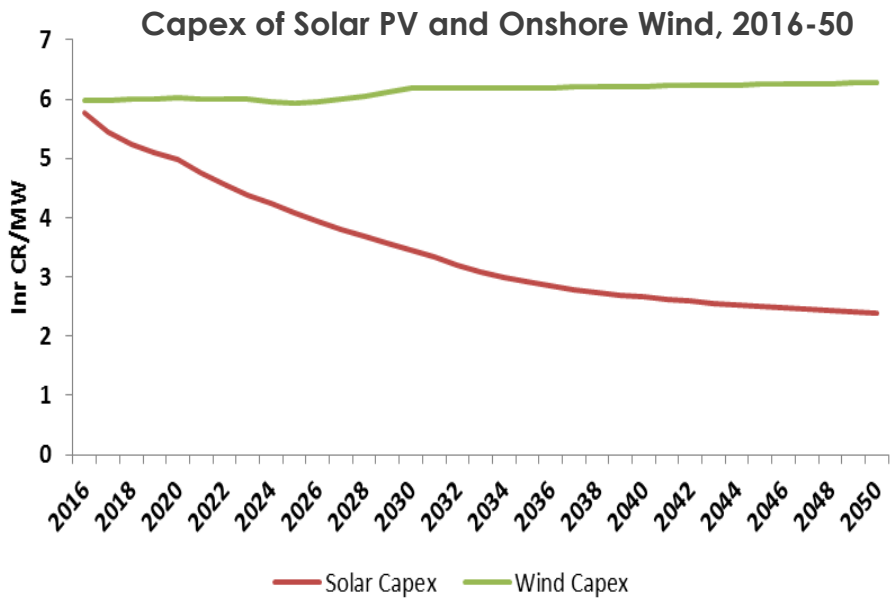
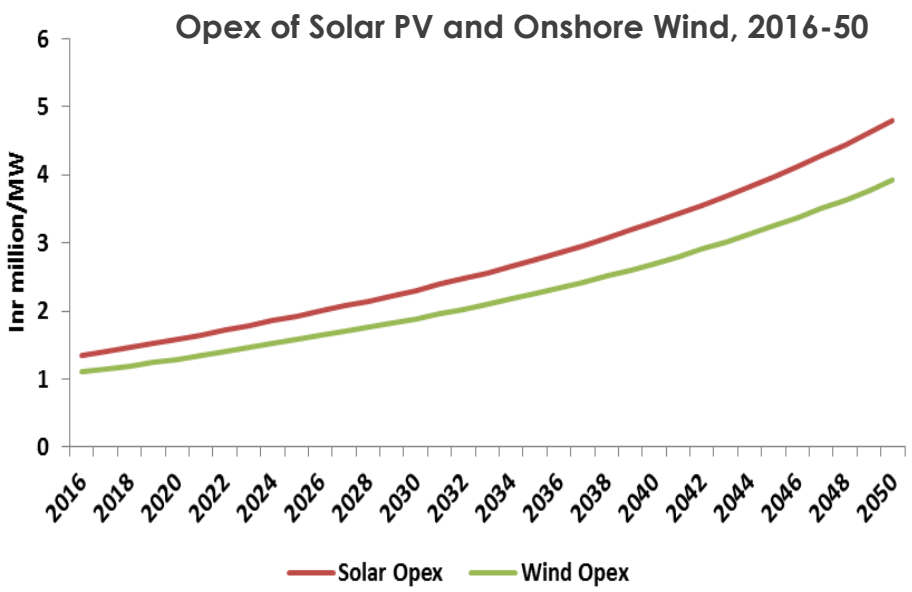
Appendix

Solar PV and wind power costs (1)

- While wind power capital expenditure (capex) may increase marginally, solar PV capex would likely reduce from INR 5.8 crore/MW in 2016 to INR 2.39 crore/MW by 2050, driven by reduction in module prices.
- Operating expenditure (opex) of solar PV and wind power from INR 1.4 mn/MW and INR 1.1 mn/MW to INR 4.8 mn/MW and INR 3.9 mn/MW respectively by 2050 driven by domestic inflation trend.





Solar PV and wind power costs (2)

- Onshore wind LCOE would likely remain flat in the range of INR INR 5.5-5.9/kWh during 2016-50.
- Solar PV LCOE would likely reduce from INR 6.8/kWh in 2016 to a low of INR 4.6/kWh in 2037 and then increase to INR 5.4/kWh by 2050.
  - Reduction in capex would likely slowdown after 2037, while opex continues to increase.