

# PATHWAYS TO ATMANIRBHAR BHARAT (SELF-RELIANT INDIA)

Harnessing India's Renewable  
Edge for Cost-Effective Energy  
Independence by 2047

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Lawrence Berkeley National Laboratory  
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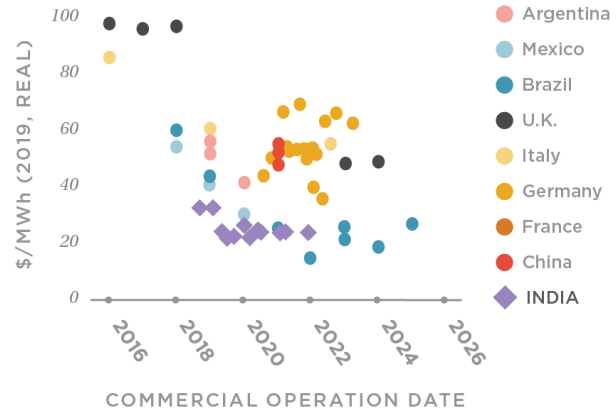
**INDIA ENERGY &  
CLIMATE CENTER**

# India can achieve energy independence and near-zero emissions by 2047

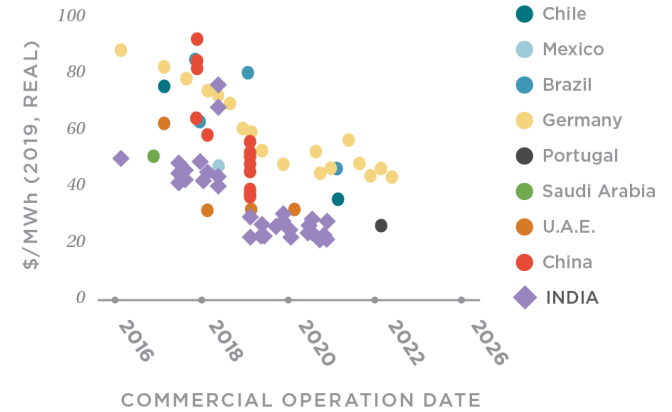
- Given the dramatic reduction in clean energy costs, India can economically:
  - Nearly eliminate oil imports with transport electrification
  - Achieve inflation proof, yet dependable, electricity by meeting new demand with renewable energy
  - Eliminate coal imports from industry by using green hydrogen and electrification
  - **Energy independence and near-zero emissions by 2047**
- Given the high economic growth, India still has a 10-15 years of lead time to manage a just and equitable transition
  - Domestic fossil fuel production and tax revenue is not impacted significantly until mid-2030s
  - New clean energy investments & consumer savings (>\$3T) could generate significant additional jobs
- A policy ecosystem that ensures that most of the new assets are clean, while incentivizing domestic manufacturing, is critical

# India has a unique opportunity to leapfrog to a clean energy infrastructure

LEVELIZED WIND AUCTION TARIFFS

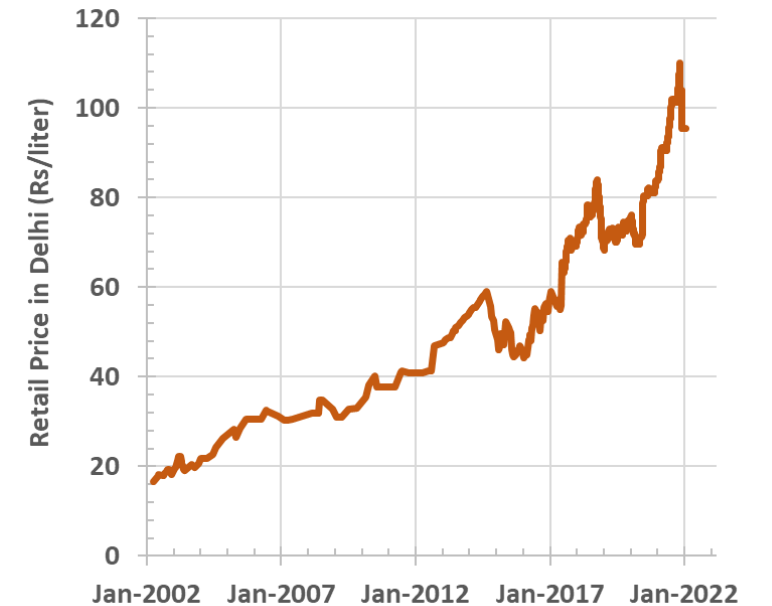


LEVELIZED SOLAR AUCTION TARIFFS

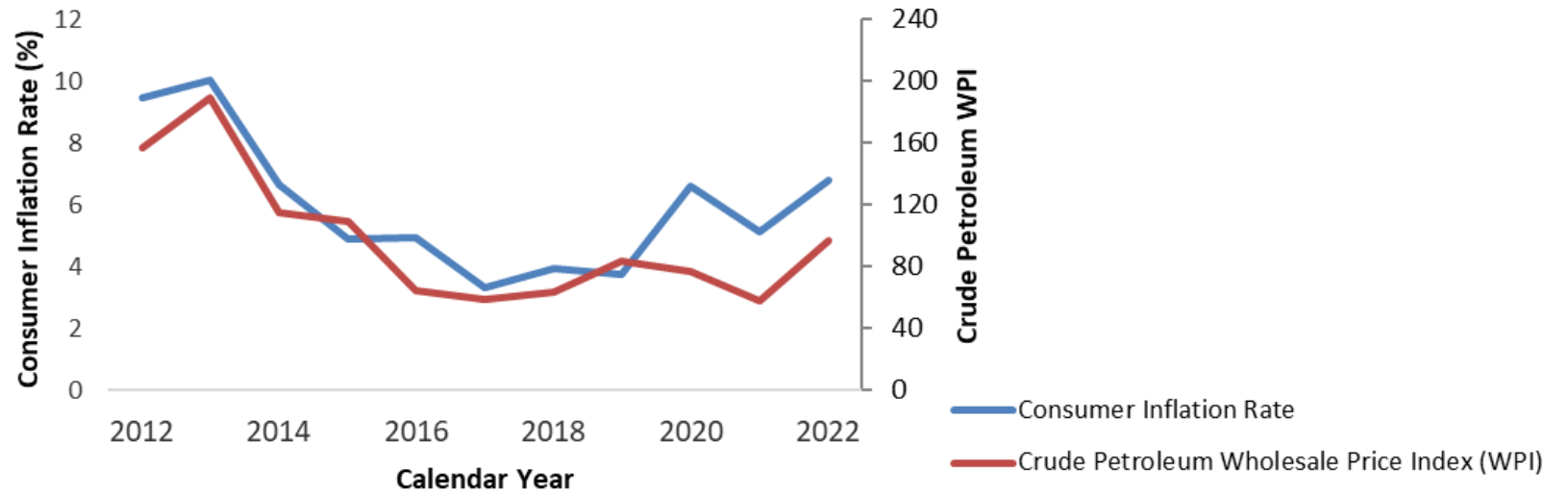


- India lags ~\$1-2 trillion in energy assets
- Clean energy is getting increasingly competitive
- Fossil fuel supply is increasingly risky in terms of supply and price
- Political-economic alignment for the energy transition is happening

RETAIL DIESEL PRICE IN INDIA (2002-22)



Dropping clean energy costs can create a more stable, sustainable economy



- **Energy Security:** Shifting to electric vehicles can avoid 90% of India's oil imports (~150 billion in 2021).
- **Cost Effectiveness:** The LCOE of renewables is cheaper than building new fossil fuel assets, operating at low-capacity factors.
- **Inflation proofing energy supply:** Renewables and EV batteries are capital assets, inflation proofing freight movement and industrial energy supply.
- **Industrial competitiveness:** EV manufacturing and green steel/cement production will be critical in maintaining industrial exports and global competitiveness.

# This study aims to assess a pathway for India to achieve energy independence — a goal set by Prime Minister Modi



The study focuses on the three largest energy consuming sectors in India – power, transport and industry – which collectively account for more than 80% of the country's energy consumption and energy-related CO<sub>2</sub> emissions. We model two scenarios:

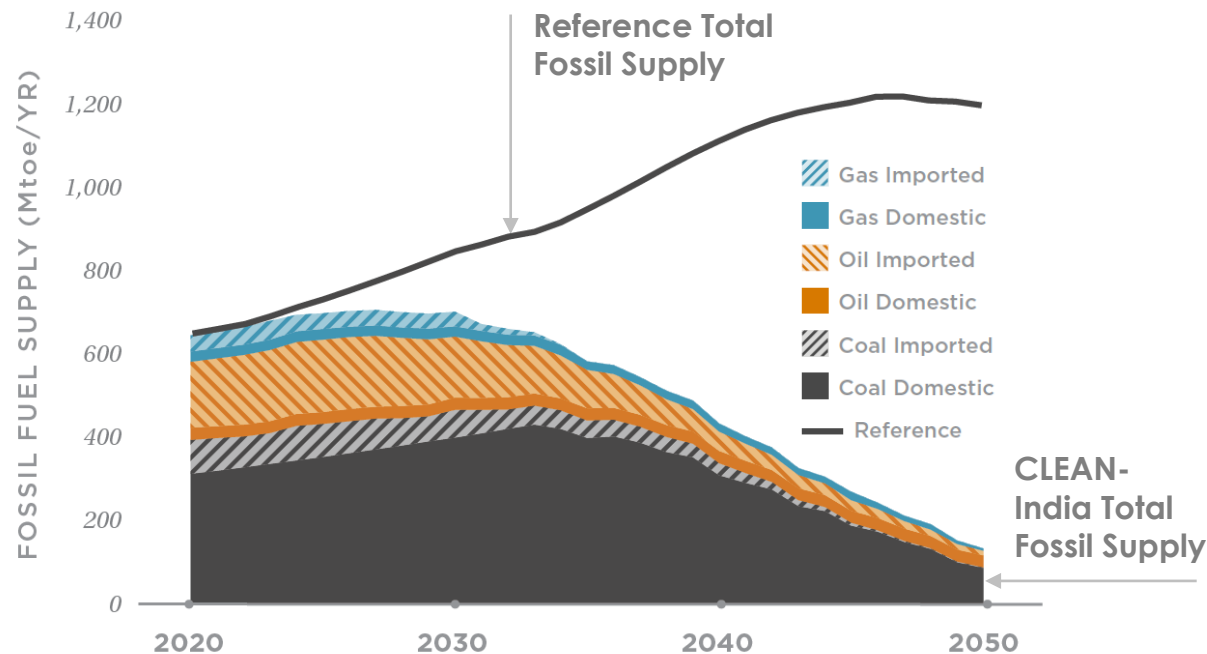
The **Reference** Scenario projects historical and recent trends in clean energy deployment, assuming progress on existing targets and commitments at the current pace of deployment.

- **Power:** >350 GW non-fossil capacity and 60% clean grid by 2047.
- **Transport:** 45% electrified new vehicle sales by 2035 for two-wheelers, 24% for passenger cars and 12% for medium and HDVs.
- **Industry:** Industrial production continues to be dominated by fossil fuels.

The **CLEAN-India** (CLEan Energy for Aatma-Nirbhar-India) scenario incorporates the potential for rapid and cost-effective clean energy deployment.

- **Power:** Achieving the current 2030 targets (>500 GW non-fossil capacity), 80% clean generation by 2040 and 90% by 2047.
- **Transport:** Nearly 100% electrified new vehicle sales by 2035 in all vehicle categories.
- **Industry:** Green H<sub>2</sub> based and electrification-based iron and steel, cement, and fertilizer/chemical/petrochemical production.

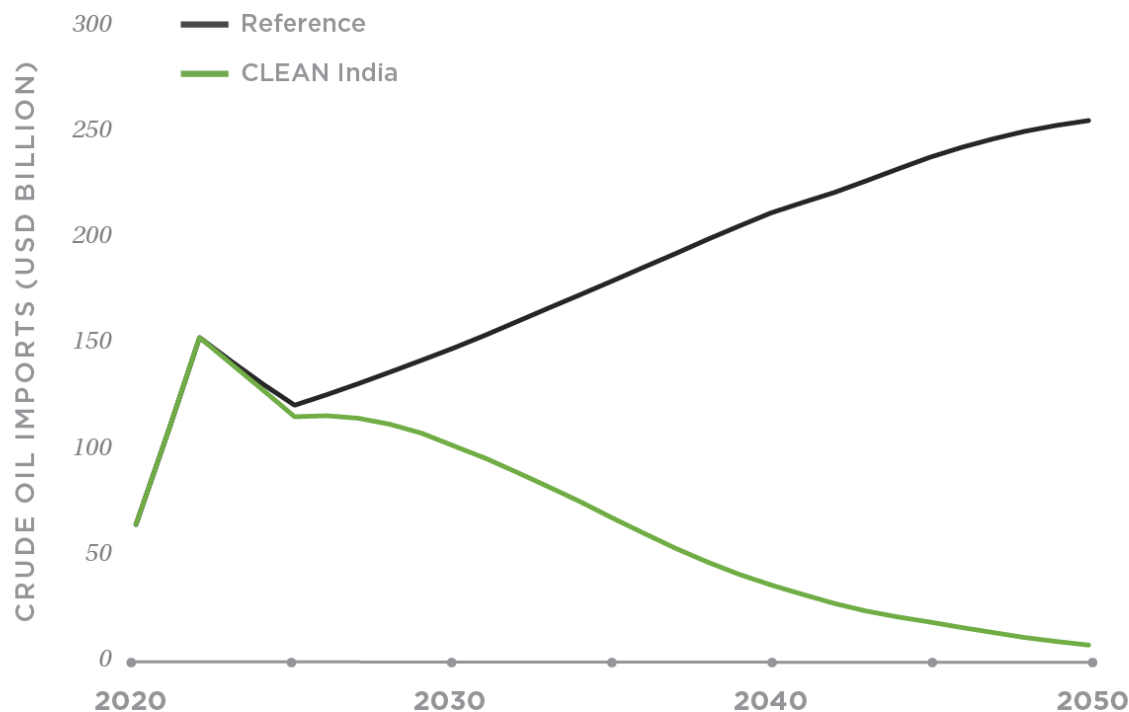
# The CLEAN India pathway can enable India's goals of energy independence



In the CLEAN-India scenario, fossil fuel imports reduces by over 90%, with oil imports decreasing below 30 mtoe and industrial coking coal imports reducing to below 5 mtoe.

Domestic coal production peaks in the late 2030s, and domestic oil production is not impacted until mid-2040s because most of India's oil is imported.

# The CLEAN India pathway nearly eliminates fossil fuel imports by 2047

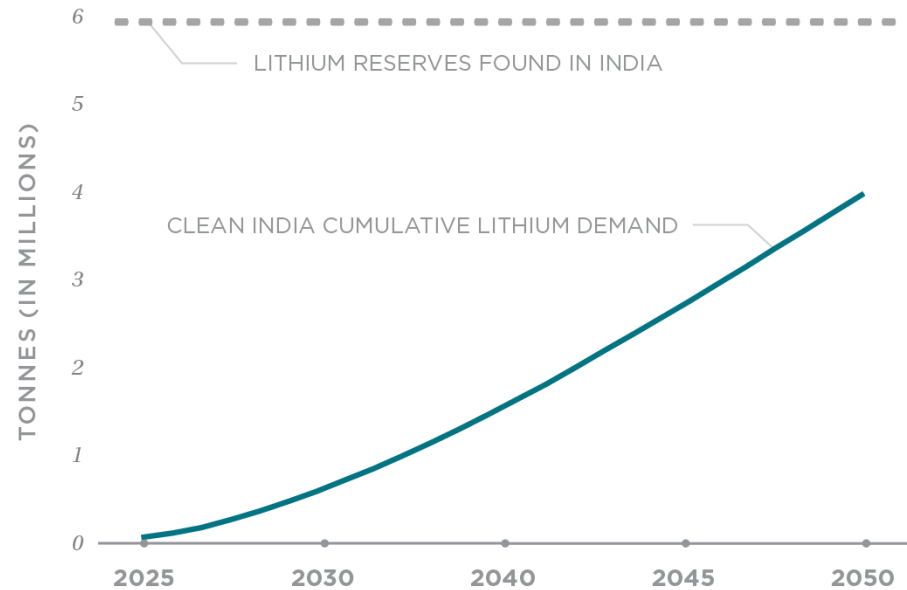


The CLEAN-India pathway can achieve energy independence by 2047 by significantly decreasing the amount of oil imported for road transportation and coal imported for industry and power sectors. By 2047, crude oil imports reduce by ~90% (\$240 billion/year), compared to the Reference case.

# Lithium demand could be met by domestic resources

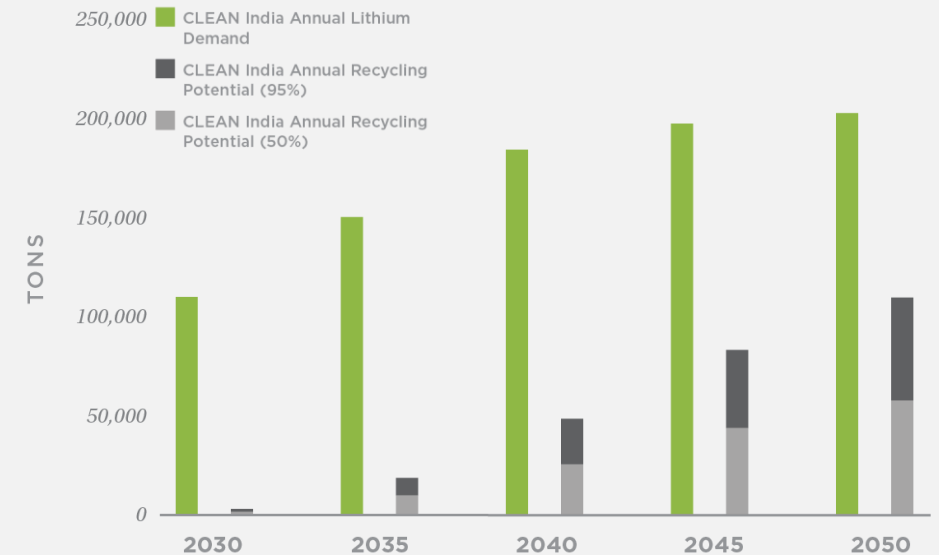
Cumulative lithium demand in the CLEAN India pathway (~1.9 million tons by 2040 and ~3.9 million tons by 2050) could be met by newly discovered lithium resources (5.9 million tons of inferred reserves).

## Lithium Reserves and Cumulative Lithium Demand



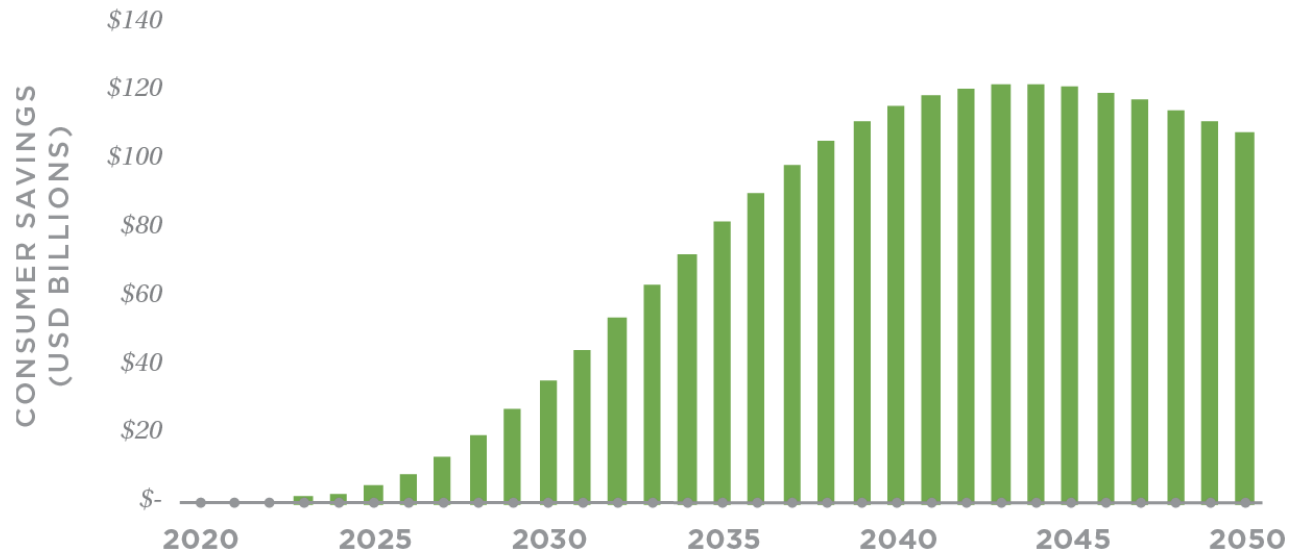
Additionally, between 25-50% of this lithium demand could be met by recycling by 2050.

## Annual Lithium Demand and Annual Lithium Recycling Potential





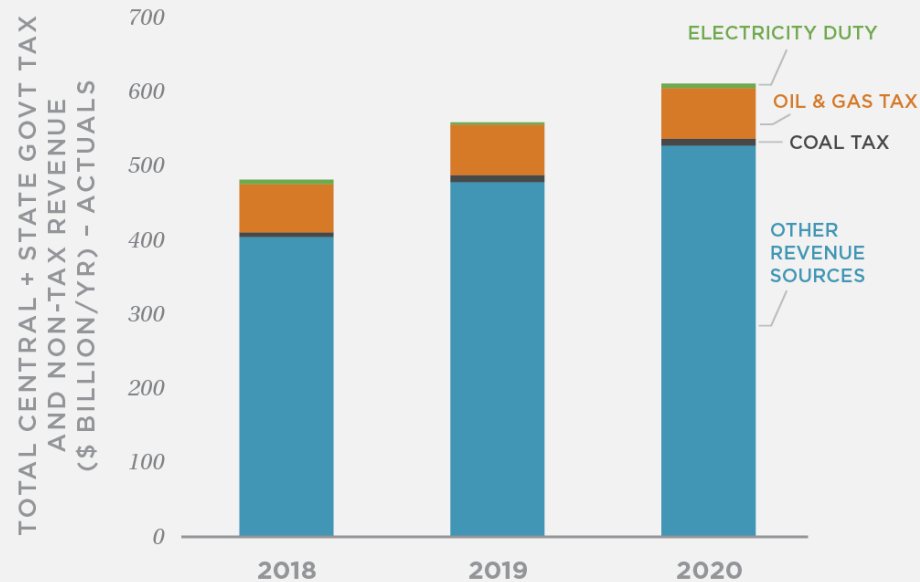
# Electric Vehicles Would Save Consumers \$2.5 Trillion between 2023-2050



- Due to transport electrification, consumers save a total of 2023-2050 would be USD ~2.5 trillion (~average \$85 billion/year), even after accounting for the higher upfront costs of electric vehicles.
- Consumer benefits far outweigh the loss in the fossil tax revenue
- Large consumer savings would lead to significant induced jobs

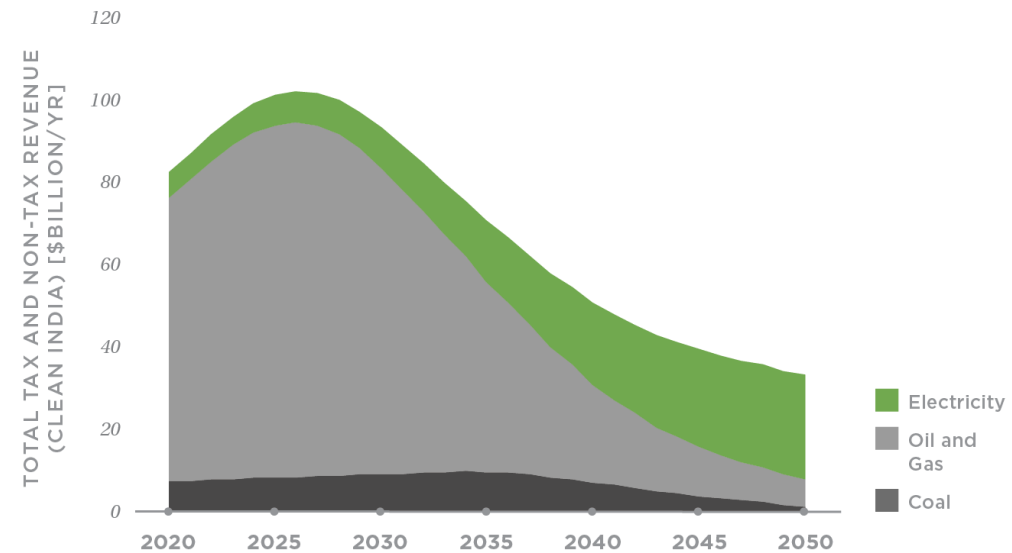
# The impact on fossil tax revenue would be manageable

Fossil fuel taxes/duties/royalties + electricity duty contribute significantly to the state + central government exchequer (~\$80 billion/year or ~12% of total government revenue).



Most of the fuel tax revenue comes from the petroleum sector (~\$68 billion/yr)

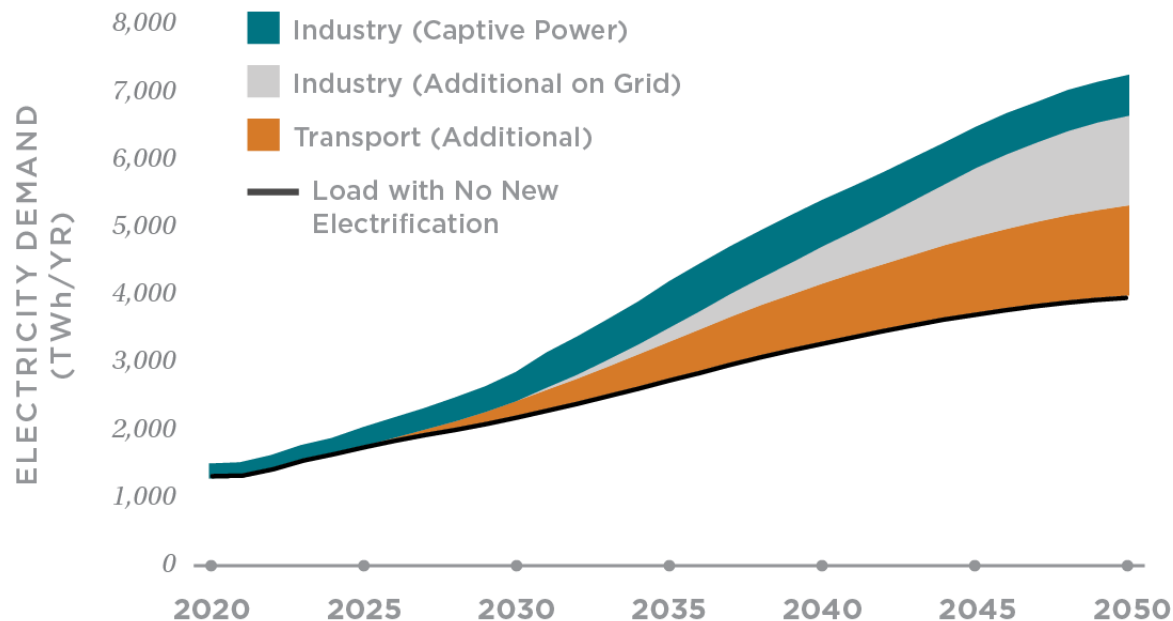
In the CLEAN India case, fossil fuel + electricity tax revenue does not reduce below the 2020 levels until 2035, assuming the same tax regime continues. By 2050, the fossil tax revenue would be ~50% of the 2020 level, which is ~2-3% of the projected total government revenue).



Given the large economic growth and increasing tax base, several opportunities to recover such tax losses (~2-3% of the projected total government tax + non-tax revenue) would exist.

# In the CLEAN-India case, a five-fold increase in electricity demand is expected by 2050

## Additional Electrification in the CLEAN Pathway

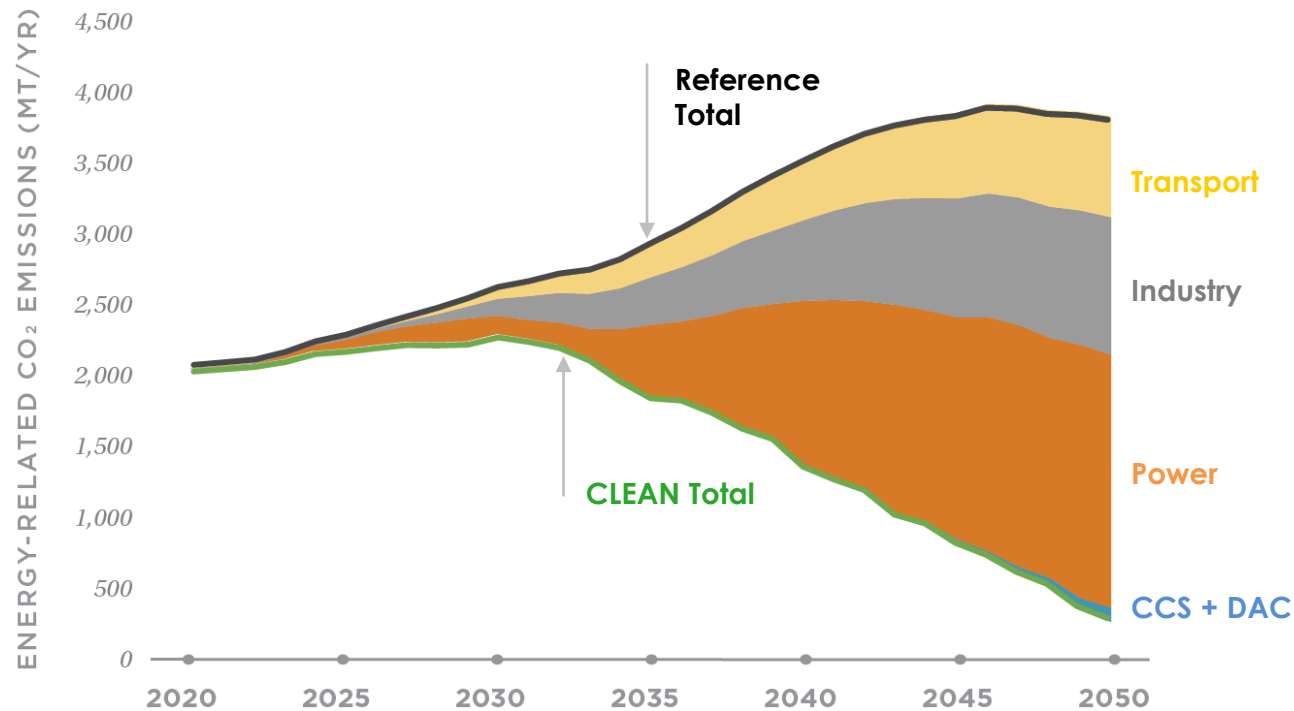


In the CLEAN India case transport and industrial electrification as well as green hydrogen production would add significant load onto the grid – (3000 TWh by 2030 and 7200 TWh by 2050).

Total electricity demand will increase five-fold between 2020 and 2050.

Future electricity load growth will be ~10% p.a., which is comparable to historical growth.

# The CLEAN India pathway would reduce energy-related CO<sub>2</sub> emissions by 90% in 2047

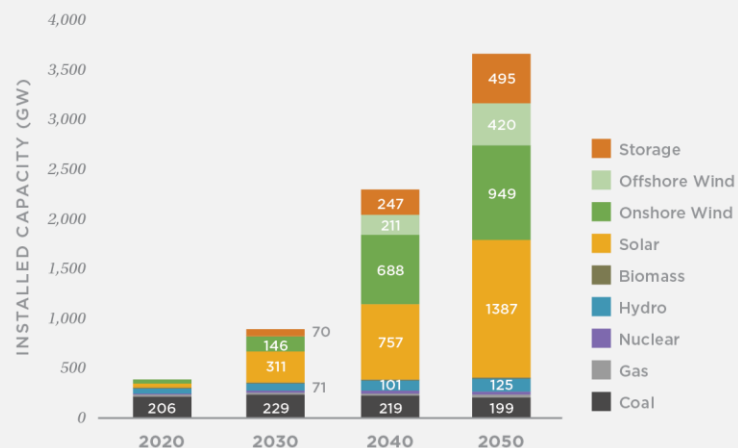


India's energy-related CO<sub>2</sub> emissions will peak in the early 2030s, before dropping to under 500 million tons/year by 2047.

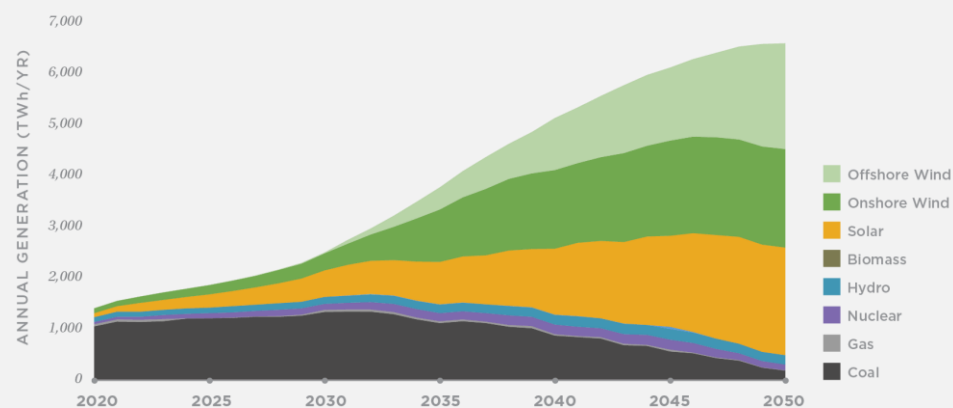
Due to the significant reduction in fossil fuel consumption, over 4 million premature deaths related to air pollution could be avoided between 2022 and 2047.

# End-use electrification + a clean power grid would require massive RE scale-up

## Installed Capacity



## Electricity Generation



### Thermal investments:

- Continue with the coal power plants that are already under construction. (2030 coal capacity = ~230GW)
- But no new coal/gas power plant beyond 2027/2028.

### RE capacity:

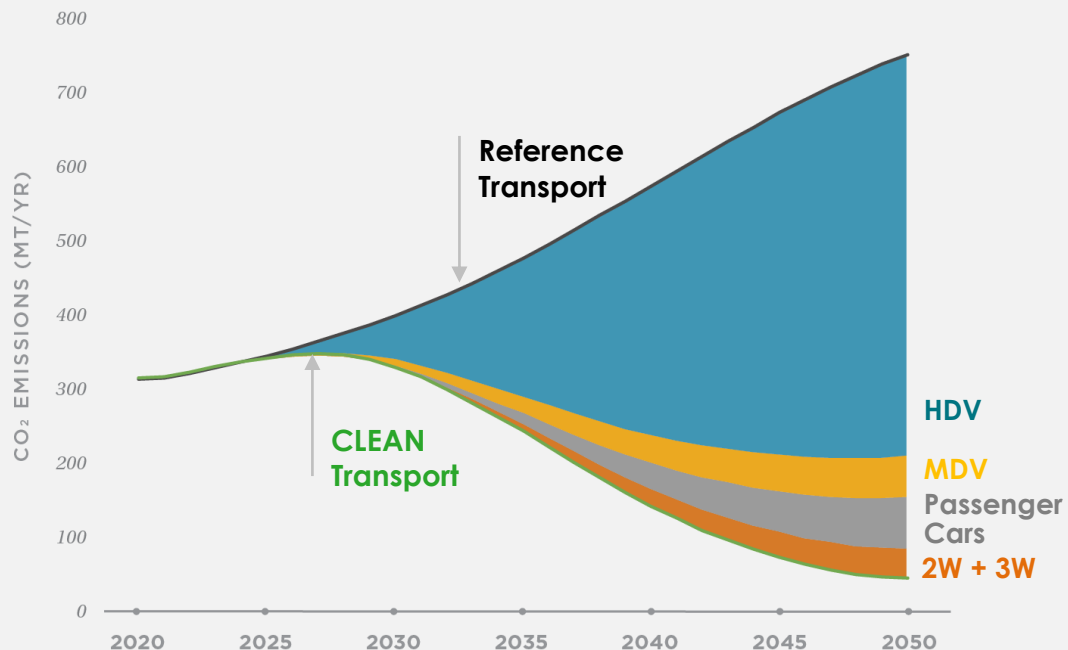
- ~500 GW total by 2030 (capacity addition of 40 GW/yr through 2030)
- ~2700 GW total by 2050 (capacity addition of ~100GW/yr between 2030 and 2050)
- Offshore wind resources (>400GW by 2050) will be critical for rapid and cost-effective RE expansion

- **Storage:** Battery storage capacity of ~60-70GW (~250 GWh) by 2030 and ~500GW (~2500 GWh) by 2050

# Electrification is critical for cost-effective, energy independent, & clean transport

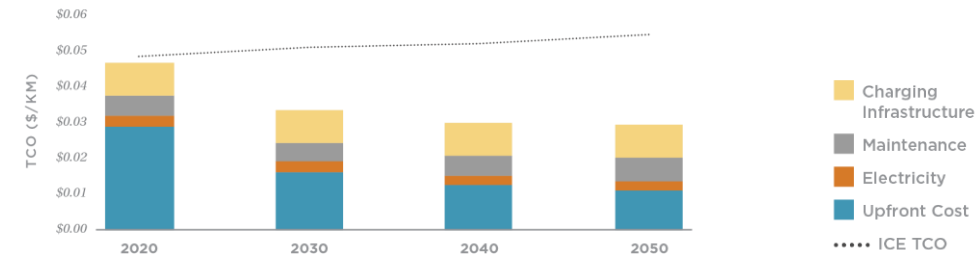
Transport sector fossil fuel use and emissions need to peak by 2030, ~70% of which will be from HDVs.

## CLEAN-India Transport Emissions Reductions

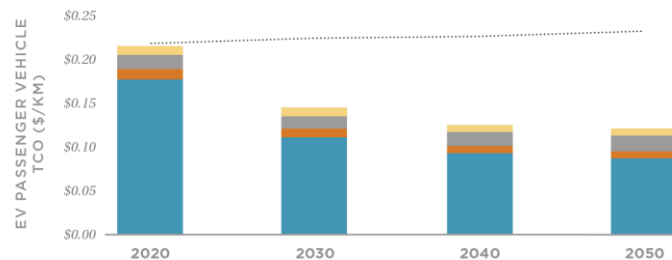


HDVs show an outsized share in emissions reduction because even in the Reference scenario, there are high levels of passenger vehicle electrification and CLEAN case HDV electrification is more ambitious.

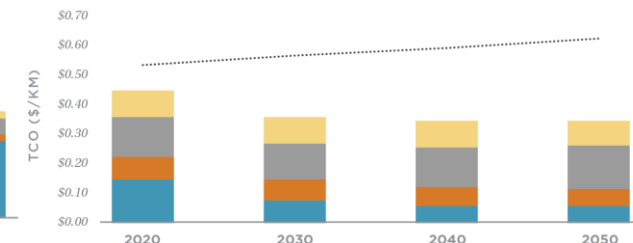
### TWO WHEELERS - EV



### PASSENGER VEHICLES - EV



### HEAVY COMMERCIAL VEHICLES (>12 TONS) - EV



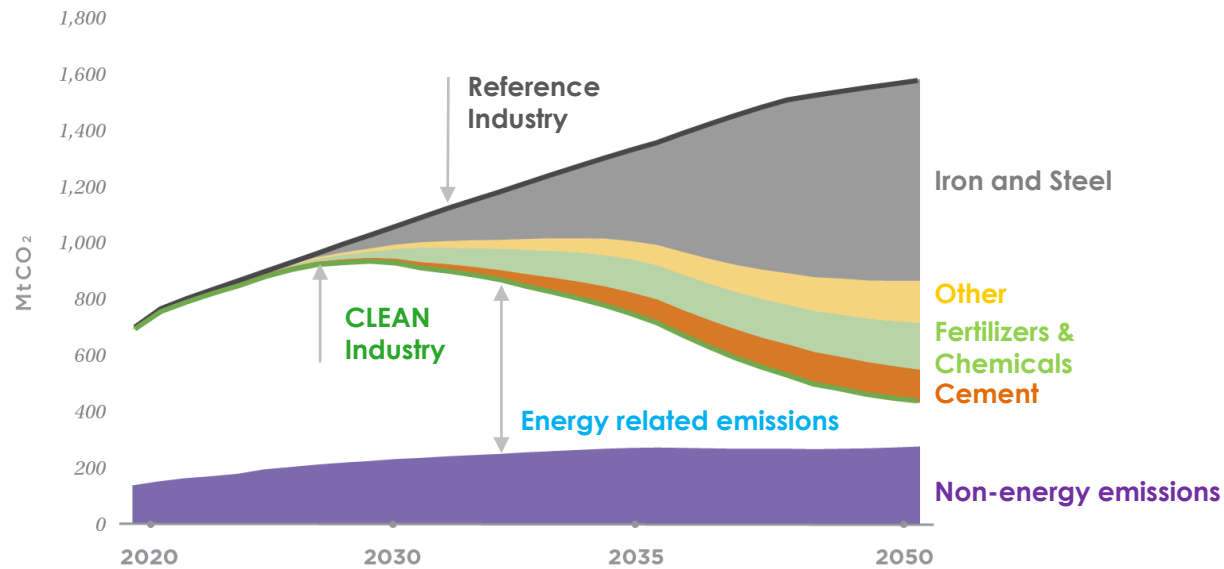
Although EVs have higher capital costs, their TCO is already lower or comparable with ICE vehicles and they achieve upfront price parity by 2030.

Priority policies focus on aggressive near / medium term vehicle electrification (focused on HDVs and fleets) and expanding EV manufacturing to maintain the global competitiveness of the Indian auto industry.

# Industrial decarbonization will need significant technology and policy innovation

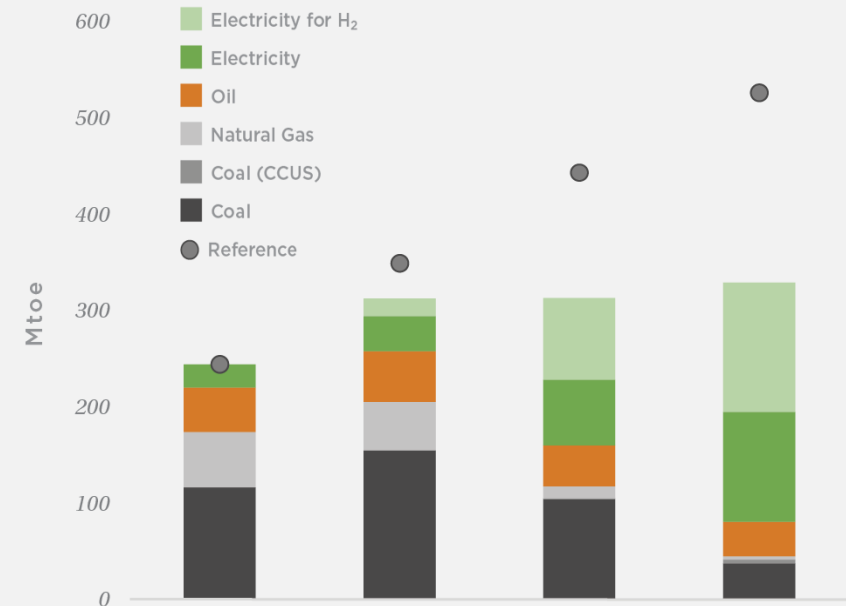
- Industrial emissions peak by early 2030 but significant non-energy emissions would remain by 2050.
- Technology innovation + scale + policy innovation is critical for cost-effective industrial decarbonization.

## CLEAN-India Industry Emissions Reductions



- Electrification and green hydrogen are the key strategies for industrial decarbonization.
- Achieving the economic viability of green hydrogen should be a priority.

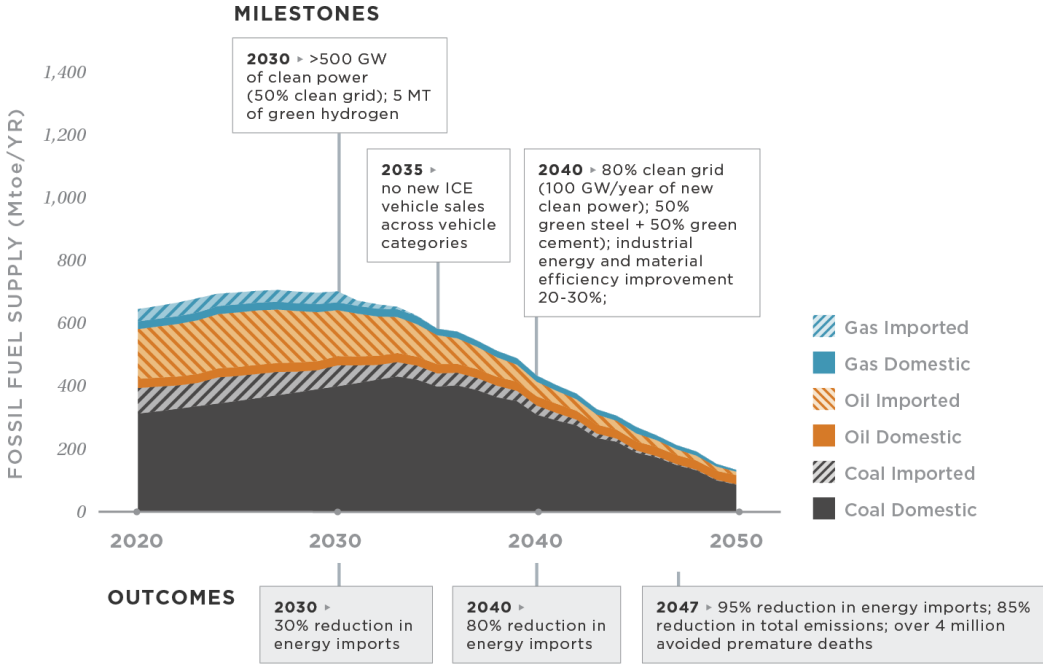
## Total Industrial Energy Consumption, CLEAN-India vs Reference



# The CLEAN-India Pathway will Require a Robust Policy Ecosystem



SECTOR	MANDATES	INCENTIVES	DOMESTIC MANUFACTURING	INFRASTRUCTURE PLANNING	UPFRONT CONSIDERATION OF A JUST TRANSITION
<b>Power</b>	Renewable Purchase Obligation / Storage Purchase Obligation	Long duration storage, offshore wind	Production Linked Incentive + Strategic Alliances for manufacturing solar panels, batteries, electrolyzers etc	Cross-sectoral least-cost investment planning	Safety Nets Worker Retraining Social Dialogue Economic Diversification
<b>Transport</b>	Zero Emissions Vehicle Sales Mandate	Public EV Procurement (e.g. buses)		Public Fast Charging + Low-Cost Solar Charging	
<b>Industry</b>	Clean Mandate on new Industrial Facilities and Hydrogen Production, energy and material efficiency standards (e.g. expand PAT)	Green hydrogen pilots, RD&D		Hydrogen Infrastructure and Low-Cost Solar PPAs	





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# Thank You!

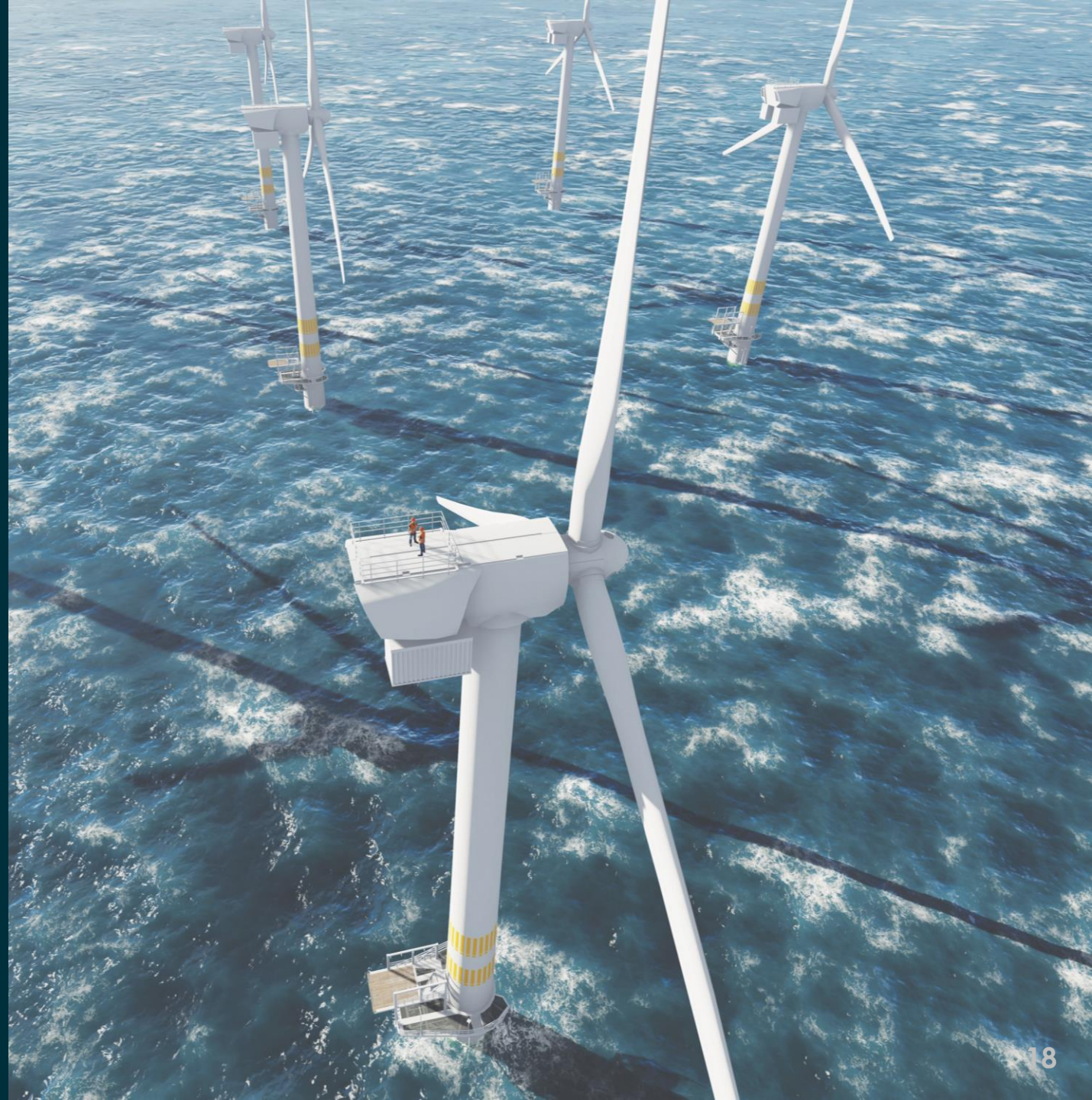
You can read the full report [here](#).

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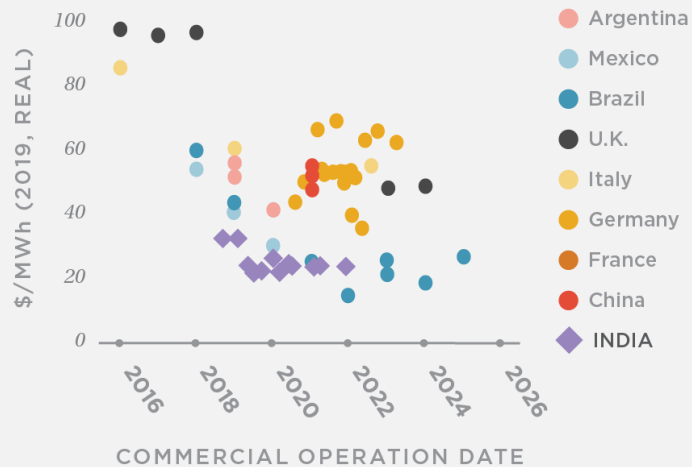
# Additional Material



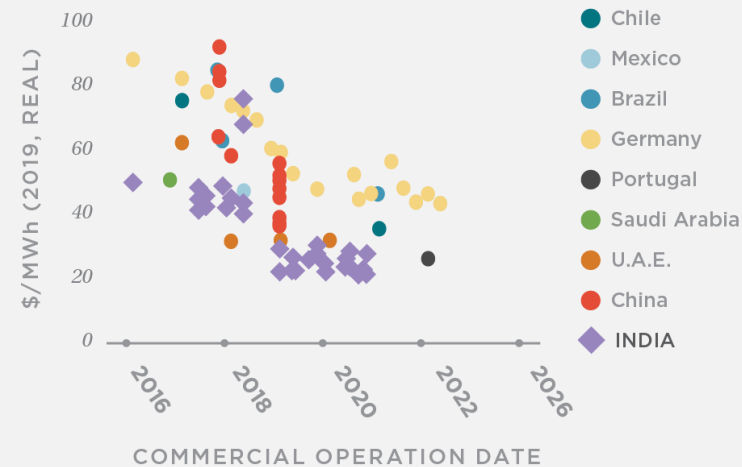
# Clean energy prices have dropped by over 80-90% in the last 10 years

## India has achieved lowest solar and wind prices globally

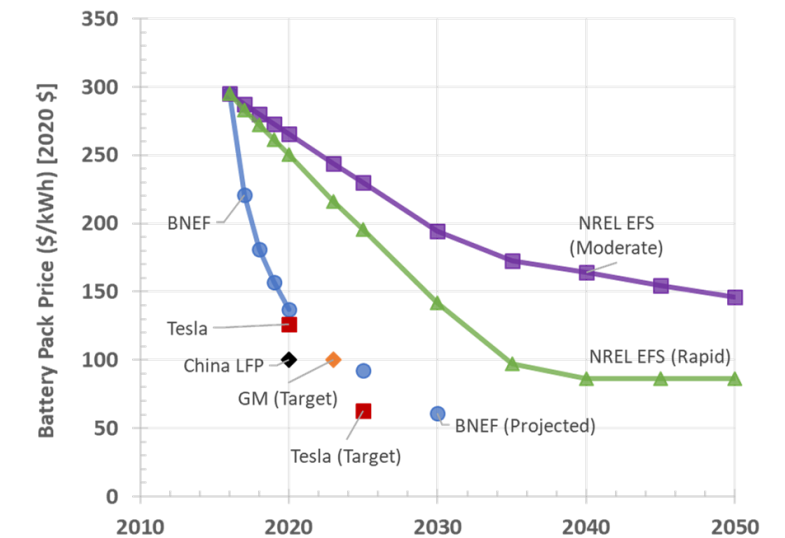
LEVELIZED WIND AUCTION TARIFFS



LEVELIZED SOLAR AUCTION TARIFFS



## Battery price reductions have arrived much earlier than anticipated



## Key Policy Assumptions

SECTOR	POLICY LEVER	REFERENCE SCENARIO	NET-ZERO SCENARIO
<b>Transport</b>	EV Sales Mandate (% of new vehicle sales)	2W/3W: 23% by 2030, 60% by 2040, 70% by 2050 Cars: 15% by 2030, 30% by 2040, 60% by 2050 Taxi/TNC: 23% by 2030, 60% by 2040, 70% by 2050 MDV/HDV: 7% by 2030, 15% by 2040, 35% by 2050	2W/3W: 50% by 2025, 100% by 2035 Cars: 50% by 2025, 100% by 2035 Taxi/TNC: 25% by 2025, 85% by 2030, 100% by 2035 MDV/HDV: 20% by 2025, 80% by 2030, 100% by 2035
<b>Power</b>	% of carbon-free electricity generation	23% in 2020 37% by 2030 (39% of native power demand) 50% by 2040 60% by 2050	23% in 2020 46% by 2030 (50% of native power demand) 80% by 2040 90% by 2050 3 % Carbon Capture, Utilization and Storage (CCUS) / Direct Air Capture by 2050
	Appliance energy efficiency	~2-3% improvement per yr 2020-2030 ~1-2% improvement per yr 2030-2040 ~0.5-1% improvement per yr 2040-2050	~4-6% improvement per yr 2020-2030 ~2-4% improvement per yr 2030-2040 ~1-2% improvement per yr 2040-2050 (~13% net demand reduction over Reference case by 2050)
<b>Industry</b>	Electrified production (% of total)	Iron & Steel: 15% by 2050 Cement: 0% in 2020 (actual), 15% by 2050	Iron & Steel: ~35% by 2050 Cement: ~65% by 2050
	Green hydrogen based production (% of total)	Iron & Steel: 0% in 2020 (actual), ~5% by 2050 Cement: 0% in 2020 (actual), ~5% by 2050 Fert & Chem & Petrochem: 0% in 2020 (actual), 25% by 2050	Iron & Steel: 10% by 2030, 40% by 2040, 60% by 2050 Cement: ~15% by 2040, ~25% by 2050 Fert & Chem & Petrochem: 50% by 2030, 100% by 2050
	Material efficiency	Steel: Recycling & scrap use (~50% by 2050) Improve Clinker to Cement ratio by 2% per decade Energy Efficiency Improvement: Steel (10% bw 2020-2050), Cement (5% bw 2020-2050)	Steel: Recycling & scrap use (~65% by 2040, 90% by 2050) Improve Clinker to Cement ratio by 5% per decade Energy Efficiency Improvement: Steel (25% bw 2020-2050), Cement (15% bw 2020-2050); F, C, & PC (15% bw 2020-2050)
<b>CCUS + DAC</b>	Share of sectoral emissions	Power: 0.5% CCUS by 2050 Industry: 1% CCUS by 2050 No DAC	Power: 2% CCUS by 2050 Industry: 5% CCUS by 2050 Economy: 1% DAC by 2050

# Clean Energy for Aatma-Nirbhar India – the CLEAN India Pathway to 2047



## Power

(Optimal capacity expansion and hourly dispatch using PLEXOS)

Achieve >500 GW of non-fossil capacity by 2030 (~50% clean);

~80% clean generation by 2040;

~90% clean generation by 2047; ~2% CCUS / DAC by 2047

Appliance / end-use efficiency: ~30% additional efficiency gain beyond market average +

demand response

## Transport

(LBNL's Faster Adoption of Clean Transportation [FACT] model)

All new vehicle sales (2W/3W, cars, trucks, including MDVs and HDVs and buses) to be electric by 2035

Public charging infrastructure buildout, especially along highways + within cities

## Industry

(LBNL's dynamic industrial stock turnover and energy model)

### Iron and Steel:

Green H2 based direct reduction (60%) + Electrification (35%) by 2050

### Cement:

Electric rotary kiln (65%) + Green H2 rotary kiln (25%) by 2050

### Fertilizer & Chemicals / Petrochemicals:

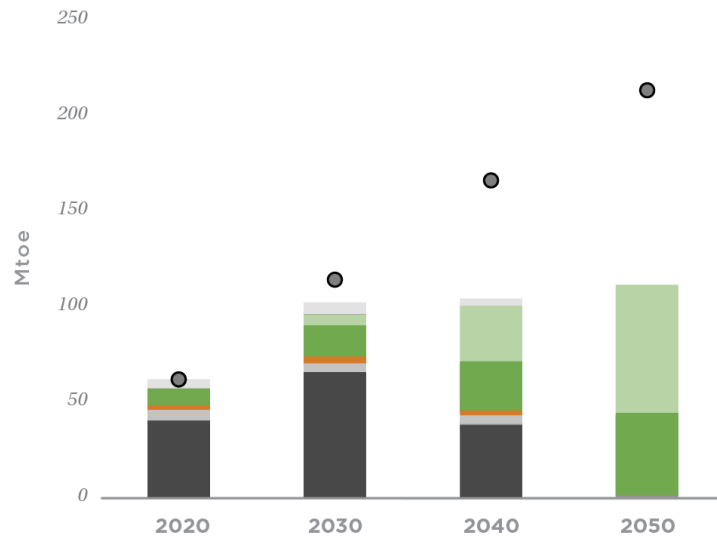
Green H2 based production (100% by 2050)

Material efficiency • Recycling • 5% CCUS

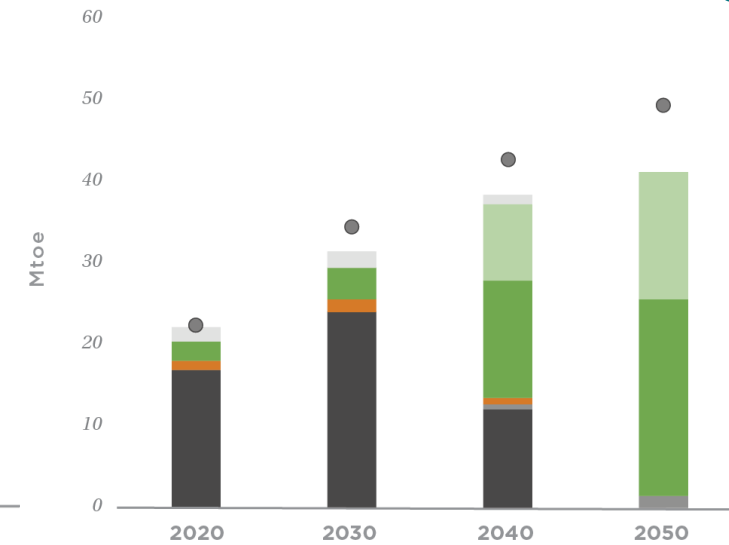
These strategies would achieve deep GHG emission reductions and enormous local environmental benefits

# Iron and Steel, Cement, and Fertilizer/Chemical/Petrochemical Energy Consumption

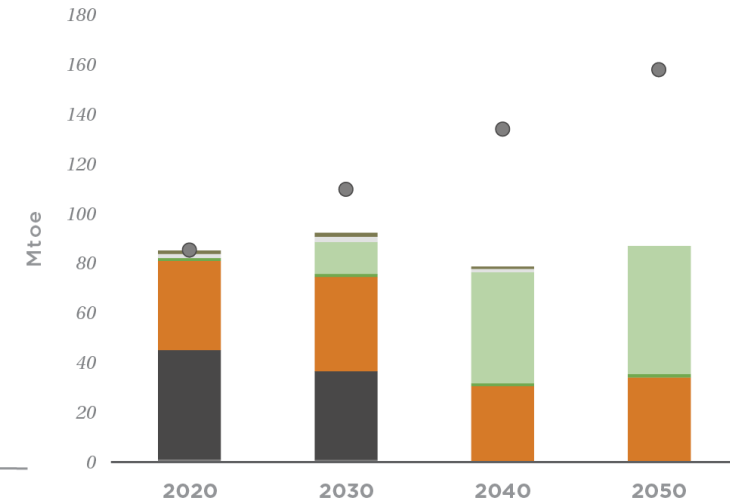
## Iron and Steel



## Cement



## Fertilizers, Chemicals, and Petrochemicals

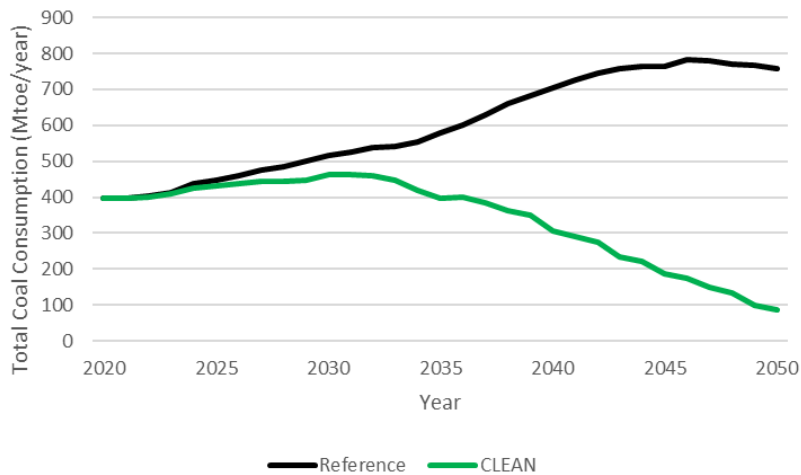


- Coal for Captive Power
- Gas for Captive Power
- Electricity for H<sub>2</sub>
- Electricity
- Oil
- Natural Gas
- Coal (CCUS)
- Coal
- Reference

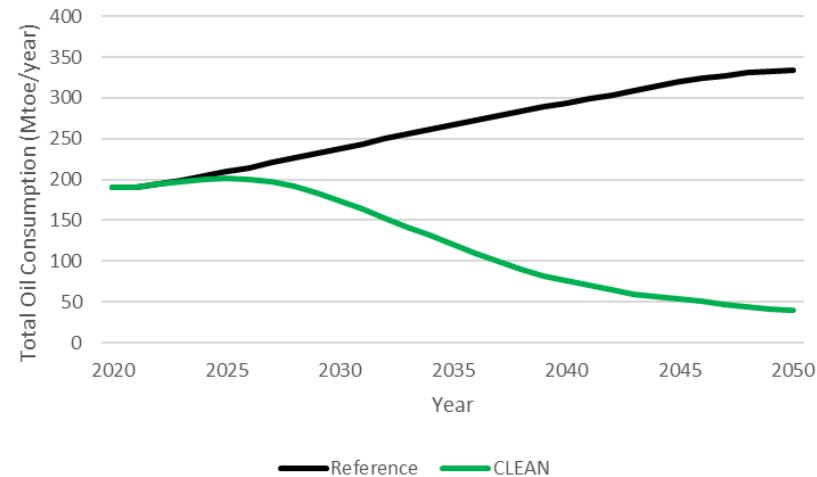
# Fossil fuel consumption does not reduce below 2020 levels until early-mid 2030s

Total economy-wide coal and oil consumption would not drop below 2020 levels before 2035, allowing for a smoother and more equitable transition e.g. unlikely to lead to fossil job losses until mid-2030s.

## Coal



## Oil



## Gas

