Harnessing India's Renewable Edge for Cost-Effective Energy Independence: Sectoral Pathways

Dr. Nikit Abhyankar, Shruti Deorah, Dr. Nihan Karali,
Jessica Kersey, Priyanka Mohanty, Dr. Amol Phadke

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Lawrence Berkeley National Laboratory
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For questions: nabhyankar@lbl.gov

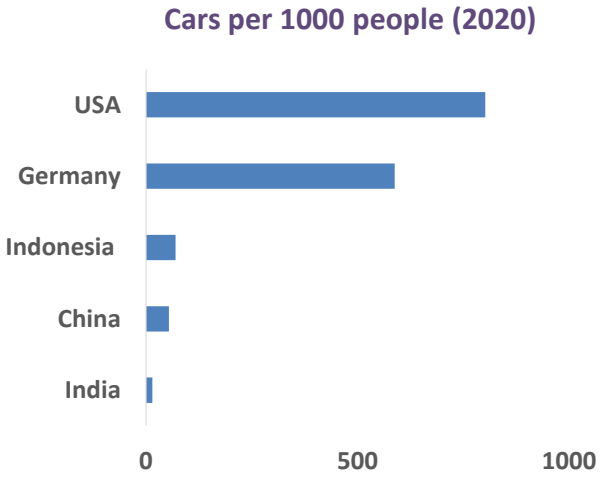
India can achieve energy independence and near-zero emissions by 2047

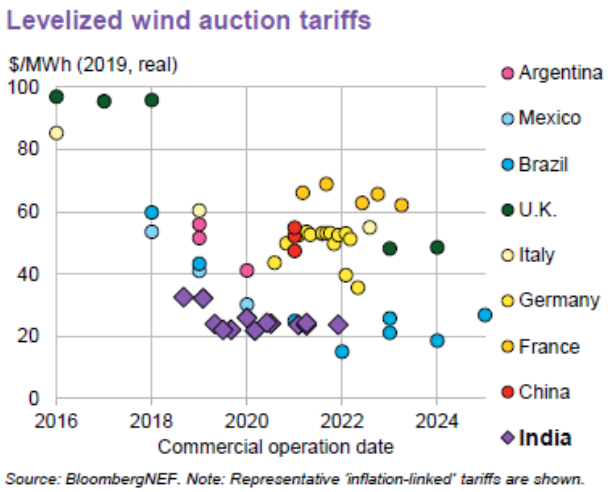
- Given the dramatic reduction in clean energy costs, India can economically:
  - Nearly eliminate oil imports with transport electrification
  - Achieve inflation proof, yet dependable, electricity by meeting new demand with renewable energy
  - Eliminate coal imports from industry by using green hydrogen and electrification
  - ➔ Energy independence and near-zero emissions by 2047

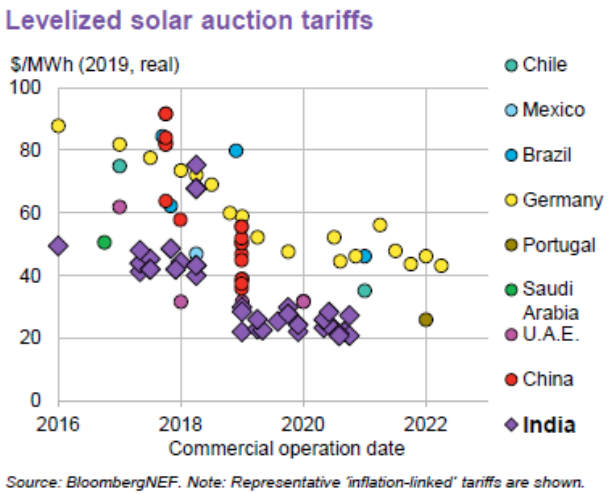
- Given the high economic growth, India still has a 10-15 years of lead time to manage a just and equitable transition
  - Domestic fossil fuel production and tax revenue is not impacted significantly until mid-2030s
  - New clean energy investments & consumer savings (>$2T) could generate over 1M additional jobs

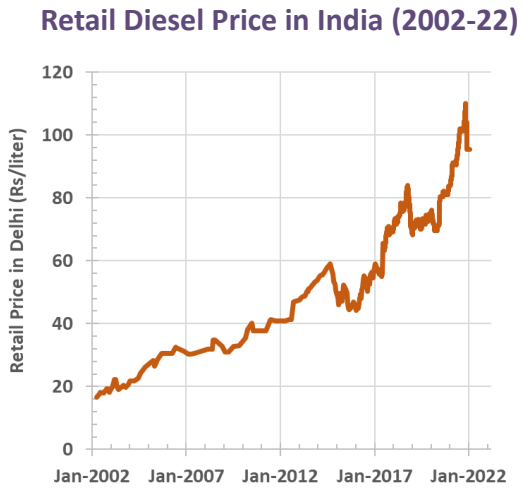
- A policy ecosystem that ensures that most of the new assets are clean is critical

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









- India lags ~$1-2 trillion in energy assets
- Clean energy is getting increasingly competitive and fossil supply increasingly risky (supply + price)
- Political-economic alignment is feasible and is already happening
- ➔ Critical to change the narrative (emissions vs energy independence; capital investment vs supply / price risks)

CLean **E**nergy for **A**atma-**N**irbhar India – the ***CLEAN India*** Pathway to 2047

Power

(Optimal capacity expansion and hourly dispatch using PLEXOS)

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

demand response

Achieve 500 GW of RE by 2030 (~50% clean);

~80% clean generation by 2040;
~97% clean generation by 2050;
~3% CCUS / DAC by 2050

Transport

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

All new 2W/3W and car sales to be electric by 2030

All new trucks and buses sales (MDV + HDV) to be electric by 2035

Charging infrastructure buildout + flexible charging

Industry

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

Iron and Steel:
Electrification +
Green H2 based direct reduction

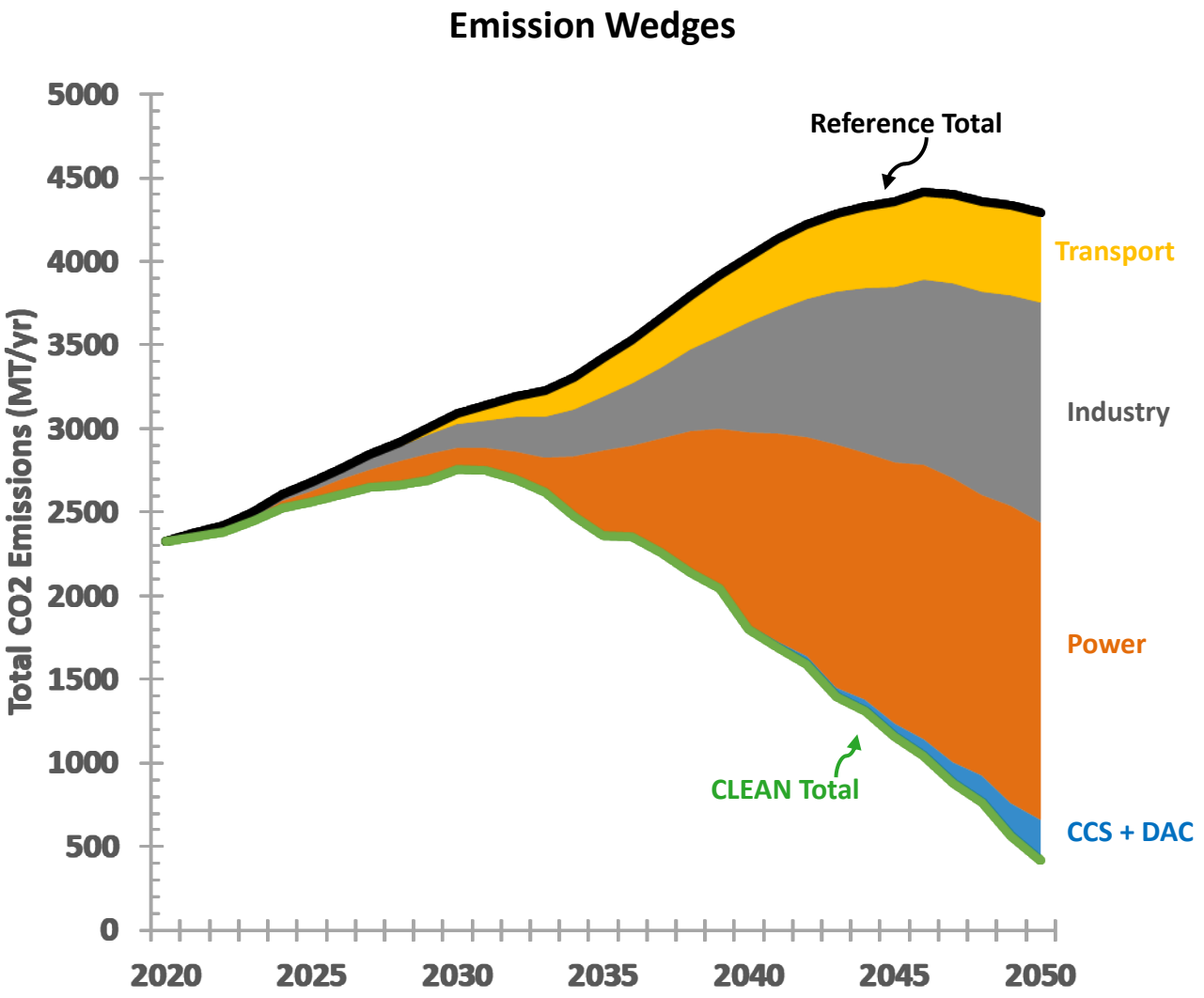
Cement:
Electric rotary kiln +
Green H2 rotary kiln

Fertilizer & Chemicals / Petrochemicals:
Electrification of low heat +
Green H2 for process / high temperature

Material efficiency (reduce need for steel+cement)
Recycling (increase scrap based steel production)
5% CCUS

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

The *CLEAN India* pathway would reduce GHG emissions to near zero by 2047-2050



In the Reference case, emissions peak by 2045 or so and start to reduce slowly.

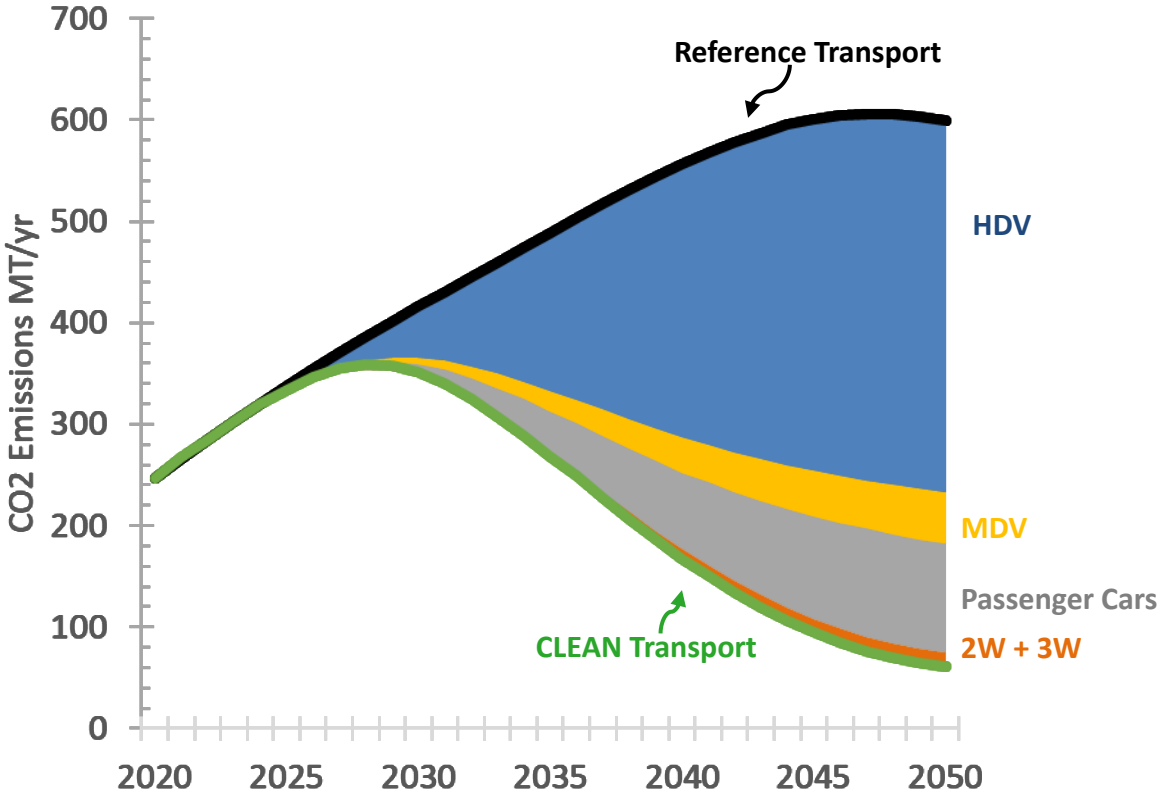
In the CLEAN pathway, emissions peak around 2030 and reach near zero around 2047-2050.

Clean power would be the largest contributor to overall emissions reduction.

Electrified transport is the largest contributor to avoiding fuel imports.

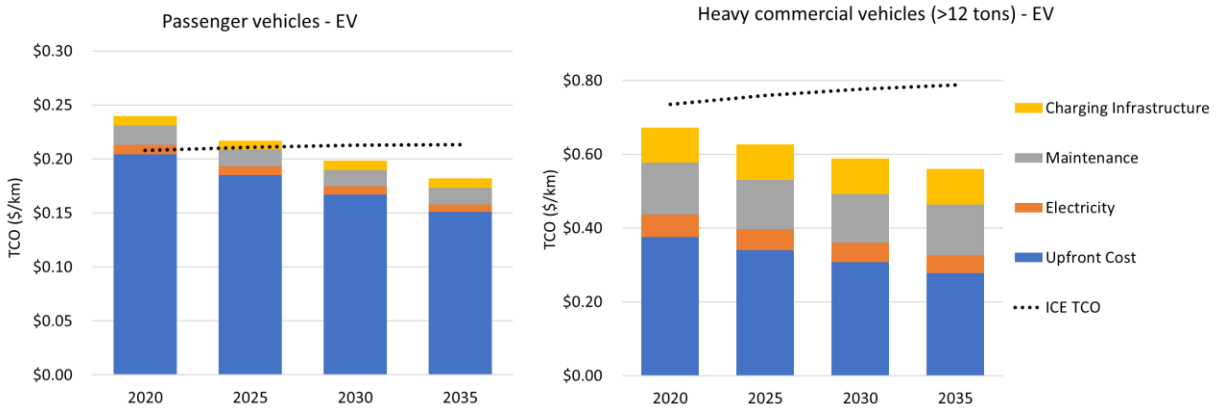
Electrification is critical for cost-effective, energy independent, & clean transport

- For achieving 2047-2050 near-zero, transport sector fossil fuel use and emissions need to peak by 2030
- ~70% of oil consumption and emission reductions will be from HDVs.



A policy framework for aggressive near / medium term vehicle electrification (focused on HDVs and fleets) should be a priority

- Although EVs have higher capital costs, their TCO is already lower or comparable with ICE vehicles



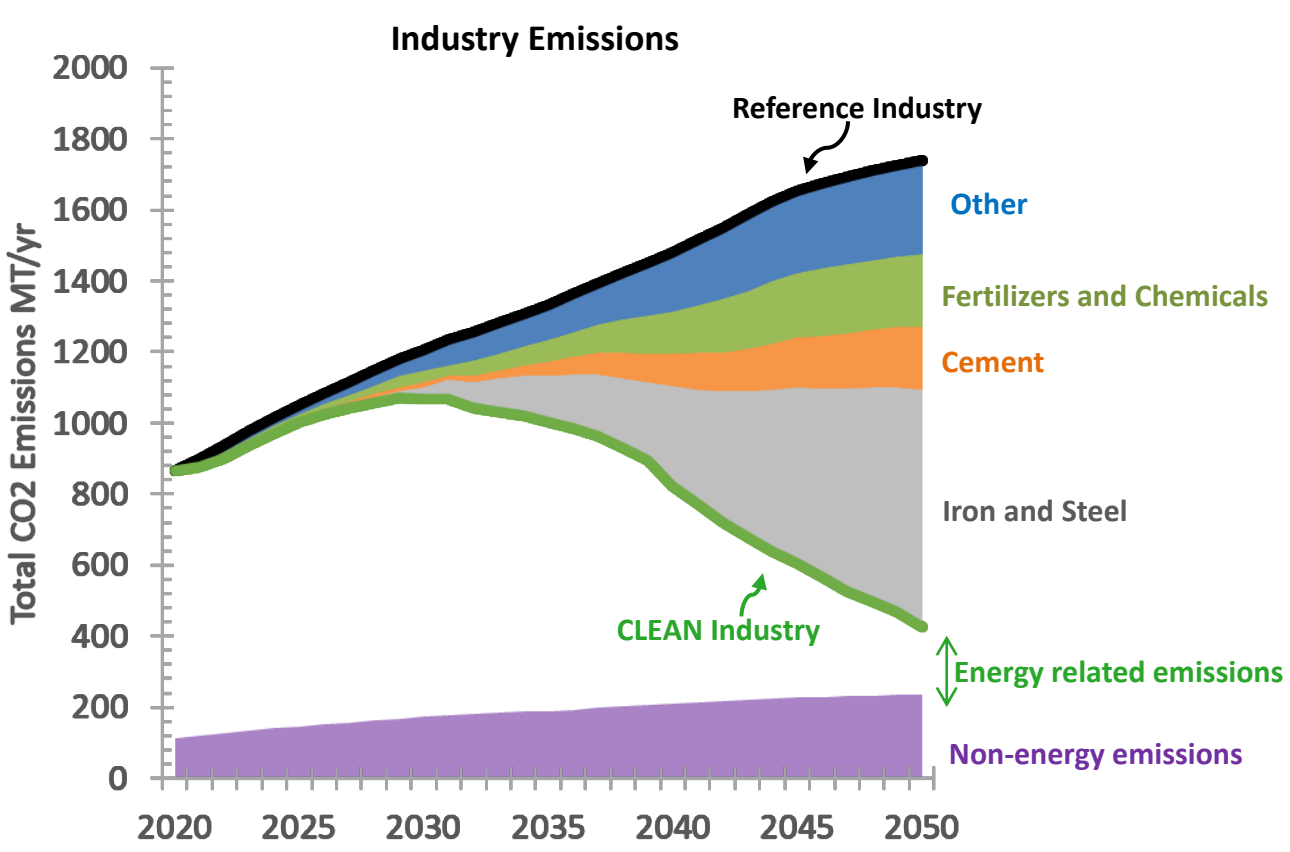
- By mid-late 2020s, EVs are expected to achieve upfront price parity

- Overall, EVs will result in massive consumer savings (e.g. payback period of <2-3 yrs by 2030)

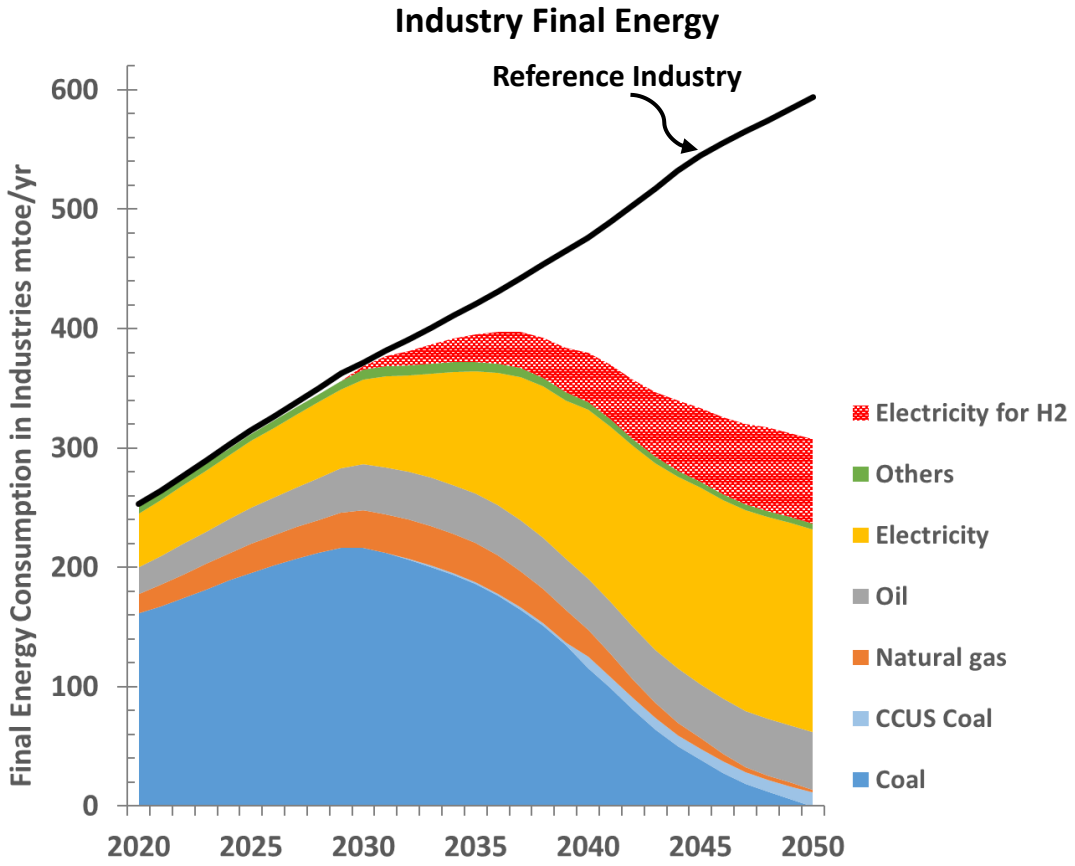
- Strategically, expanding domestic EV manufacturing is critical for maintaining the global competitiveness of the Indian auto industry

Industrial decarbonization will need significant technology and policy innovation

- Industrial emissions need to peak by early 2030
- However, significant non-energy emissions would still remain
- Would nearly eliminate the industrial coking coal imports

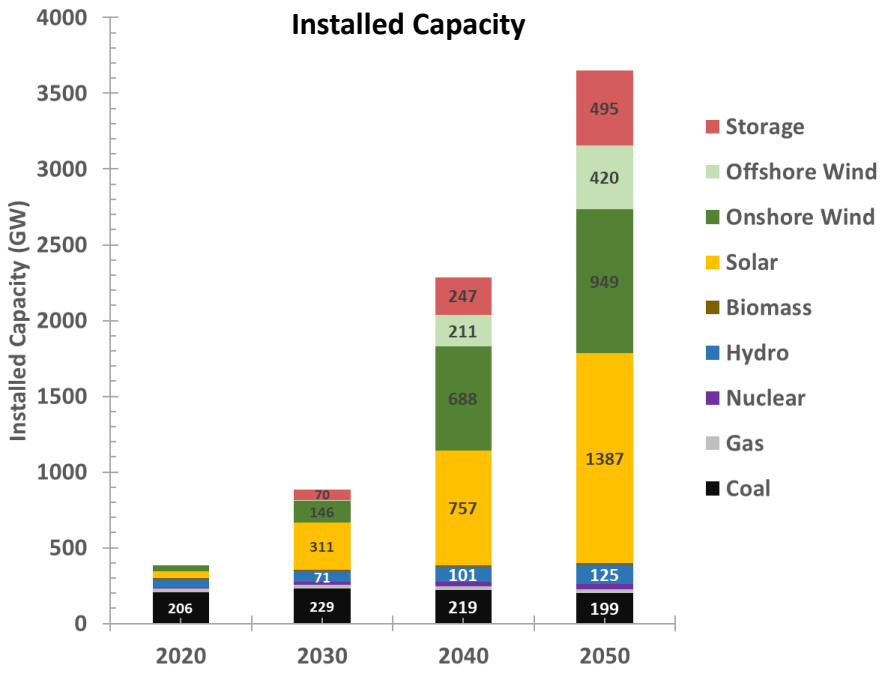


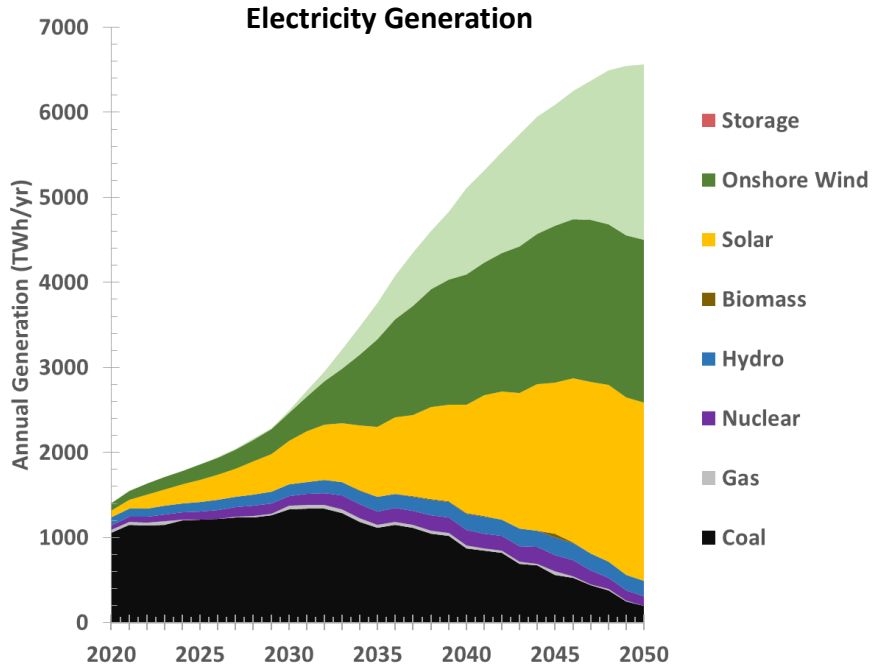
- Electrification and green hydrogen are the key strategies for industrial decarbonization
- Economic viability of H2 is still ~10 years away



➔ **Technology innovation + scale + policy innovation is critical for cost-effective industrial decarbonization**

End-use electrification + 97% clean grid would require massive RE scale-up



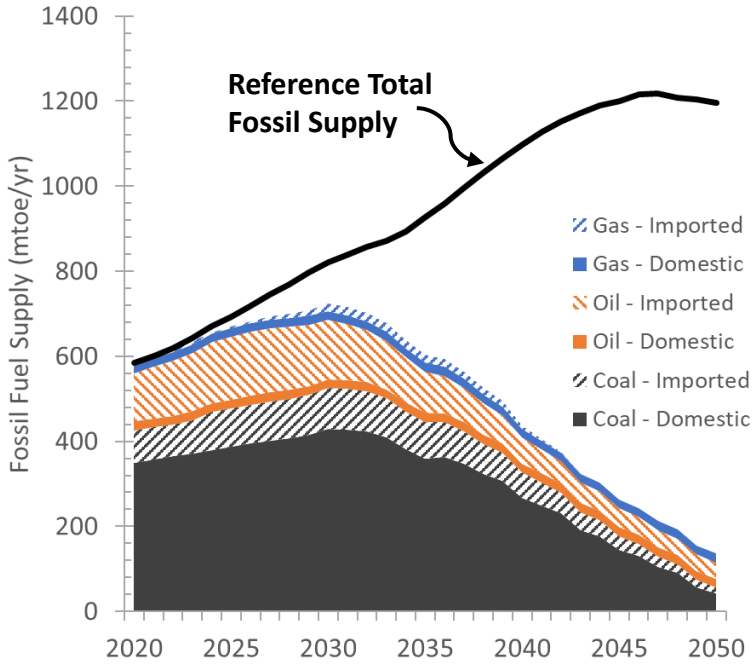


- **Thermal investments**:
  - Continue with the coal power plants that are already under construction. (2030 coal capacity = ~220-230GW)
  - But no new coal/gas power plant beyond 2027/2028.
- **RE capacity**:
  - ~500 GW total by 2030 (capacity addition of 40 GW/yr through 2030)
  - ~2700 GW total 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

The *CLEAN India* pathway nearly eliminates fossil fuel imports by 2047-2050

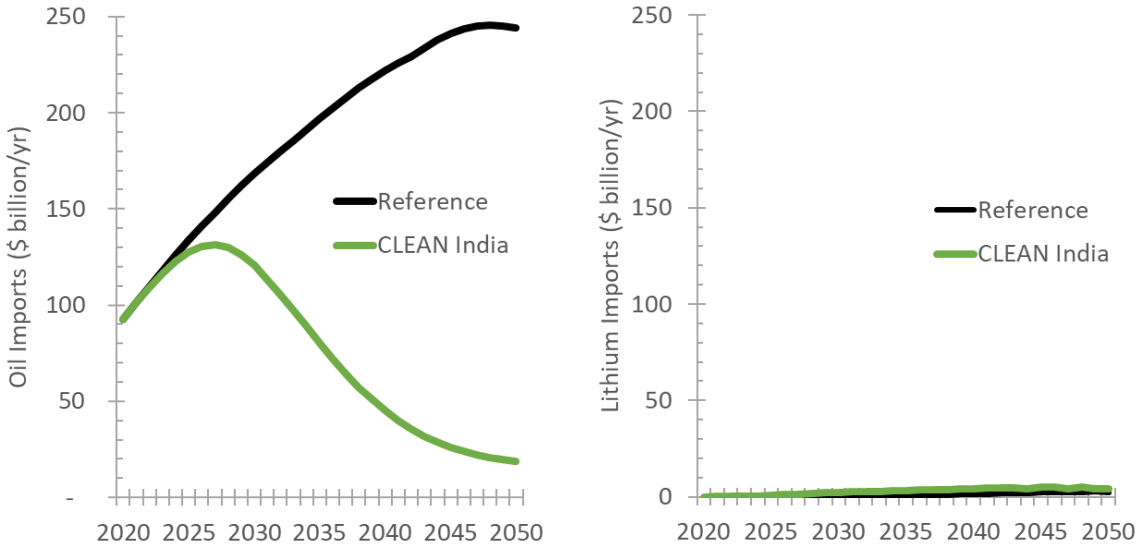
By 2050, fossil fuel imports reduce by ~95% (<$20 billion/yr), compared with >$300 bn/yr in the Reference case (~40% of primary energy)



- ***Coal***: Domestic coal production peaks in late-2030s
- ***Oil***: Because of ~90% imports, domestic oil production is not impacted until mid-2040s

Does this imply high Lithium imports ?

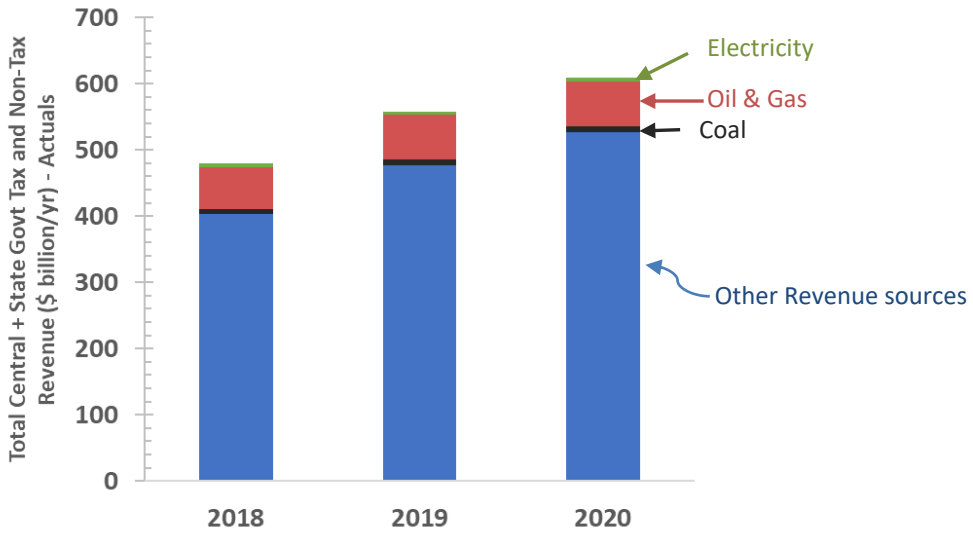
In the CLEAN pathway, >1000 GWh/yr of battery capacity would be needed by 2035-2040.



- Lithium import cost would be <2% of oil imports
- Significant domestic + strategic (bilat + quad) mining potential

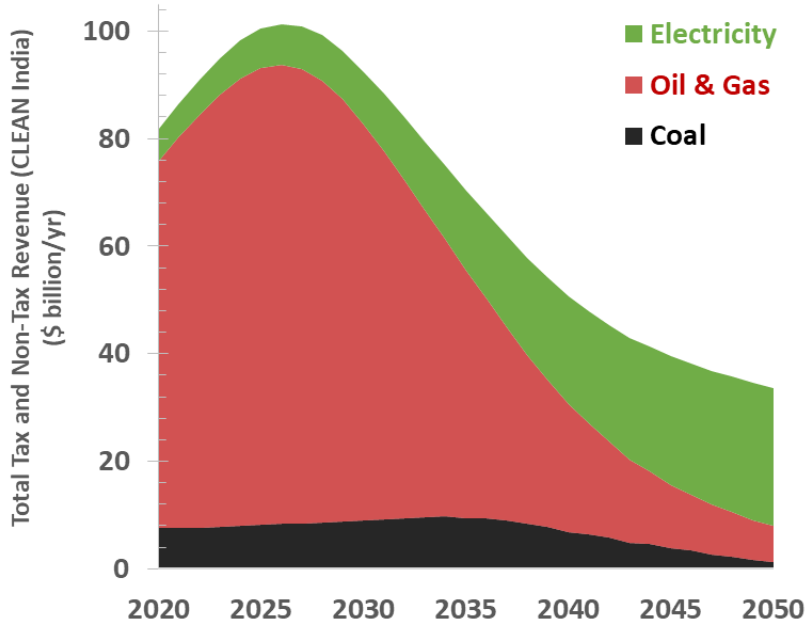
The impact on fossil tax revenue would be manageable

Fossil fuel taxes/duties/royalties + electricity duty contribute significantly to the state + central government exchequer (~$80 billion/yr 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.

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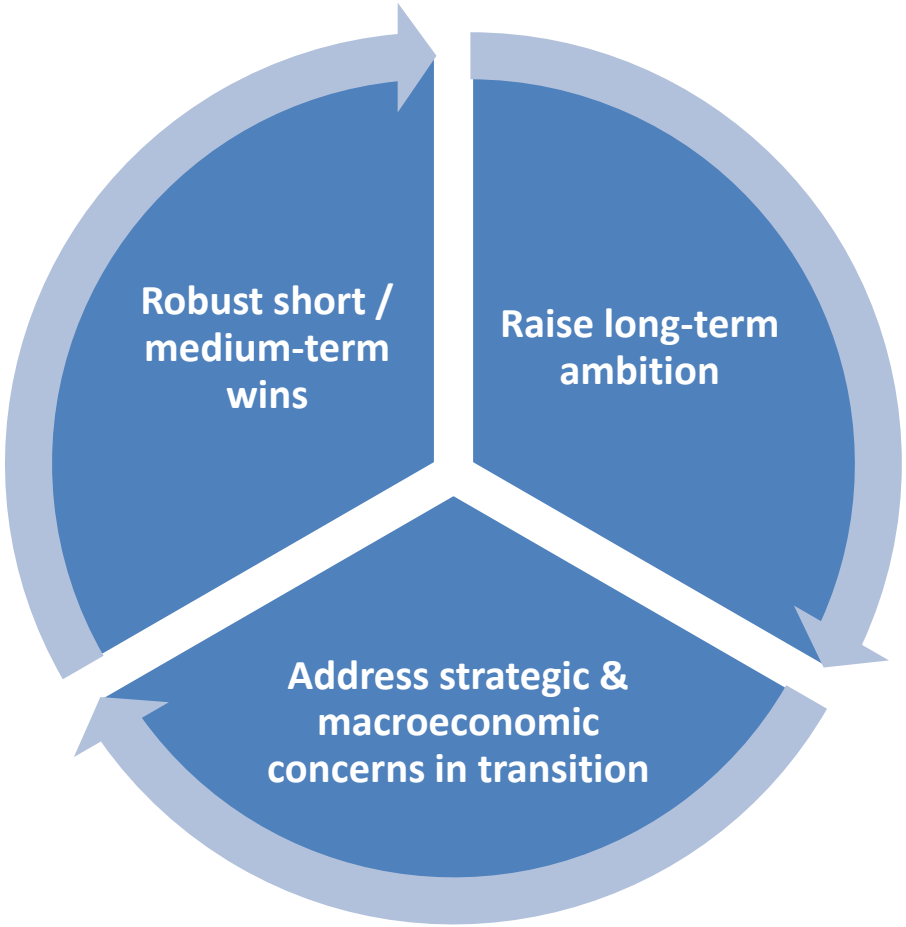
Policy priorities for the *CLEAN India* vision



Policy & deployment roadmap for power sector transformation

Already instituted:

- 500 GW/50% clean by 2030
- $3 billion of solar & battery manufacturing incentives
- RPO at state level

Short-term (3-5 years)

- Act amendment to institute Clean Energy Standard/RPO
- Storage mandates + bulk procurement
- State level regulatory framework (e.g. RA, IRP)
- Enhance wholesale electricity market (e.g. MBED)

Medium-term (5-10 years)

- Incentives for domestic manufacturing of battery + solar
- Replace coal production with power from solar+storage
- Incentives + policy framework for “firm” clean resources (e.g. offshore wind)
- Flexible power markets (e.g. capacity markets)
- New technology innovation (e.g. Iron-air batteries)

Long-term (>10-15 years)

- Massive RE + storage scale-up
- Innovative business models and land acquisition strategies
- Seasonal hydrogen production + multi-sector integration

Transport sector is poised to pivot to electrified transportation

Already instituted:

- $1.5 B FAME-II subsidies
- $3.5 B of incentives for zero-emission-vehicle production
- 5% GST on EVs (28% on ICE)
- MoP guidelines on charging infra deployment in cities and on highways

Short-term (3-5 yrs)

- Zero-emission-vehicle (ZEV) targets
- Prioritize HDVs (trucks + buses) for incentives and other policy support
- Initiate deployment of highway charging infra

Medium-term (5-10 yrs)

- Provide a ZEV trajectory
- HDV + TNC fleet electrification targets
- Build upon domestic manufacturing incentives
- Fast charging infrastructure along national + state highways + key cities
- Innovative business models for charging infra

Long-term (>10-15 yrs)

- Incentives + domestic content requirement for manufacturing
- Strategic Lithium + Other mineral reserves
- Charging infrastructure coverage all across the country
- Smart charging + smart grid

Industry would need a slew of policy interventions to decarbonize

Already instituted:

- PAT scheme for industrial energy efficiency
- Hydrogen Mission

Short-term (3-5 yrs)

- Enhanced PAT trajectory for energy/material efficiency ~10% /year
- Clean hydrogen production & usage targets
- Clean mandate on new industrial stock
- Demonstration/pilot projects for electrification of processes and hydrogen applications

Medium-term (5-10 yrs)

- Electrification of majority low-to-medium heat applications
- Scale up hydrogen production using curtailed RE to keep costs low
- Improve domestic scrap collection and sorting for scrap-based steel production (recycling)
- Invest in new technology research e.g. new metal reduction electrolysis
- Subsidize low carbon steel & cement for govt. infra projects

Long-term (>10-15 yrs)

- Hydrogen / alternative technology scale-up
- Shift industrial load to follow RE supply (TOU rates, real-time prices etc.)
- Incentives to retire existing energy-intensive stock prior to end of life

Thank You

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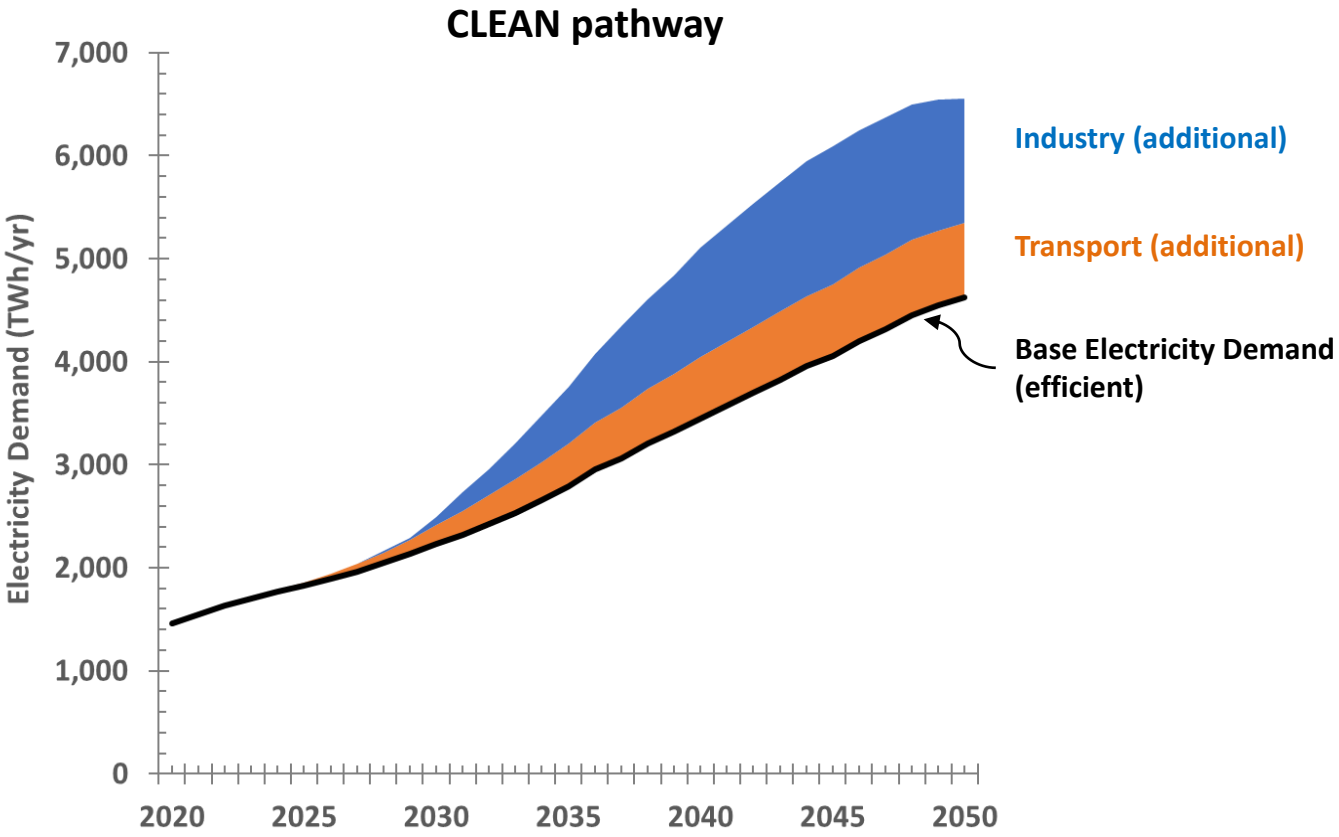
Additional Material

Key Policy Assumptions

Sector	Policy Lever	Reference Scenario	Net-Zero Scenario
Transport	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 2030 Cars: 50% by 2025, 100% by 2030 Taxi/TNC: 25% by 2025, 85% by 2030, 100% by 2035 MDV/HDV: 20% by 2025, 80% by 2030, 100% by 2035
Power	% 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 97% 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)
Industry	Electrified production (% of total)	Iron & Steel: Flat at ~30% (2020 level) Cement: 0% in 2020 (actual), ~5% by 2050 Fert & Chem: 0% in 2020 (actual), ~5% by 2050	Iron & Steel: ~35% by 2030, ~42% by 2040, ~70% by 2050 Cement: ~10% by 2030, ~15% by 2040, ~25% by 2050 Fert & Chem: ~5% by 2030, ~12% by 2040, ~16% by 2050
	Green hydrogen based production (% of total)	Iron & Steel: 0% in 2020 (actual), ~5% by 2050 Cement: 0% in 2020 (actual), ~15% by 2050 Fert & Chem: 0% in 2020 (actual), ~2% by 2050	Iron & Steel: ~5% by 2030, ~15% by 2040, ~25% by 2050 Cement: ~10% by 2030, ~50% by 2040, ~75% by 2050 Fert & Chem: ~5% by 2030, ~12% by 2040, ~16% by 2050
	Material efficiency	Baseline	Steel: Recycling & scrap use (~40% by 2040, 100% by 2050) Waste heat recapture (Fertilizer and Chemicals) Improve Clinker to Cement ratio by 5% per decade
CCUS + DAC	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

Large increase in electricity demand is expected; additional demand due to electrification is modest (~10% by 2030 and ~30% by 2050)

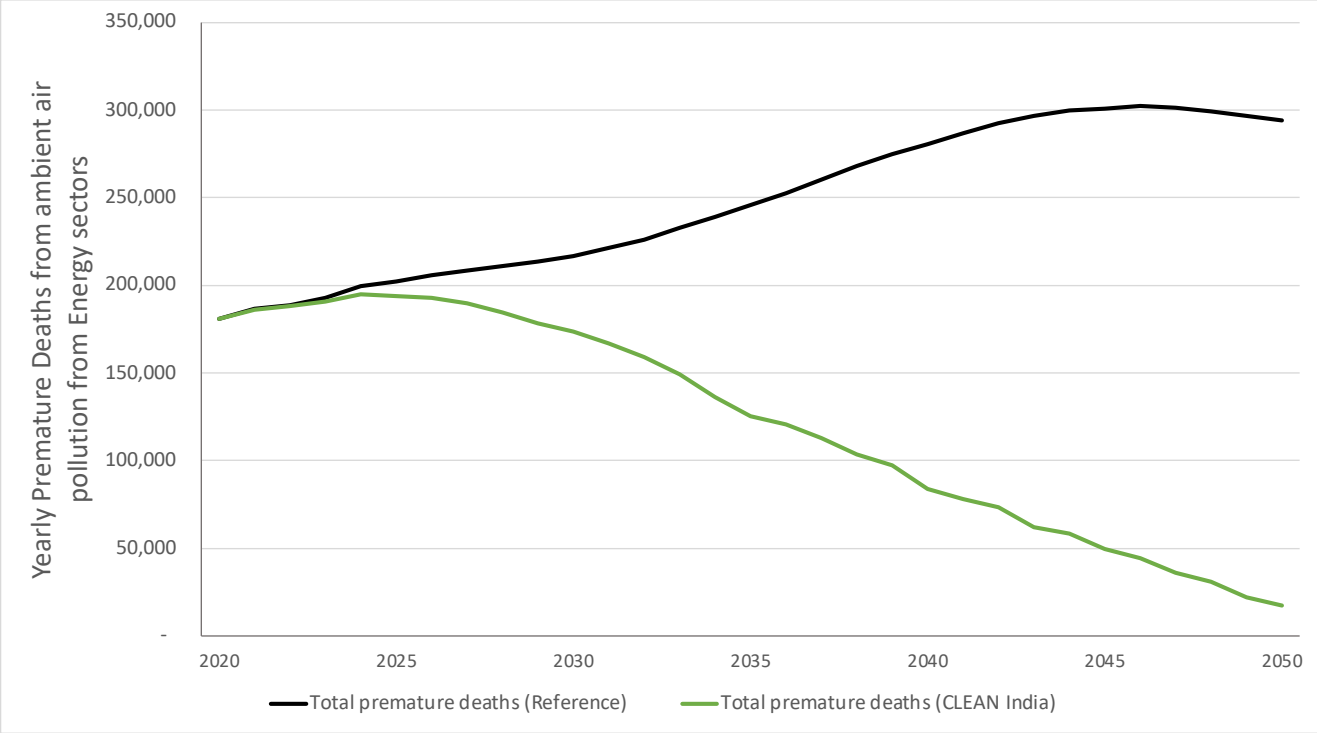


In the CLEAN case, total electricity demand will likely quadruple between 2020 and 2050.

However, additional electricity demand due to transport + industry electrification is modest (~10% by 2030 and ~30% by 2050).

Future electricity load growth, despite aggressive electrification, will be ~4-5% p.a., which is similar to the historical growth.

CLEAN India pathway could avoid ~4 million premature deaths by 2050

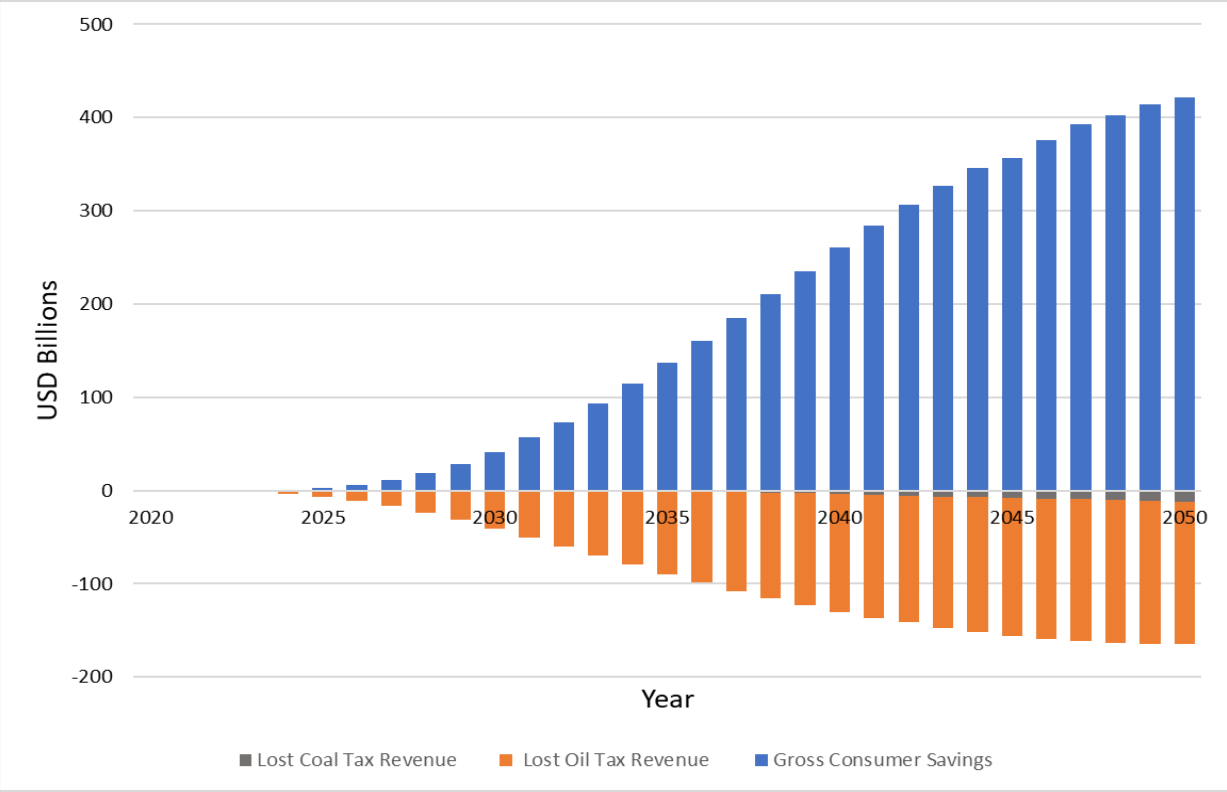


CLEAN India pathway could avoid ~4 million premature deaths through 2050, mainly driven by power and transport sector decarbonization.

Other public health benefits such as reduced morbidity are also significant.

CLEAN India Pathway would accrue consumer savings of >$2 trillion by 2050

- NPV of consumer savings 2020-2050 would be >$2.1 trillion (~average $70 billion/yr)
- Consumer benefits far outweigh the loss in the fossil tax revenue (NPV of ~$1 trillion)
- Large consumer savings would lead to significant induced jobs



If environmental benefits are included (GHG + avoided mortality and morbidity, not shown in the chart), the total benefits would be in excess of $2.5-3 trillion

Considerations for long-term transition

Jobs

- Job gains due to large investment in clean tech
- No job losses for a decade => time to plan
- Induced job growth due to cost savings

Govt. Revenues

- No reduction in tax revenues in the short run
- Consumer savings larger than lost tax revenues
- Fiscal Policy design important for win-win

Macroeconomic Benefits

- Massive reduction in oil import bill
- Insulation from fuel price shocks on CPI
- HDV charging by RE can help control inflation

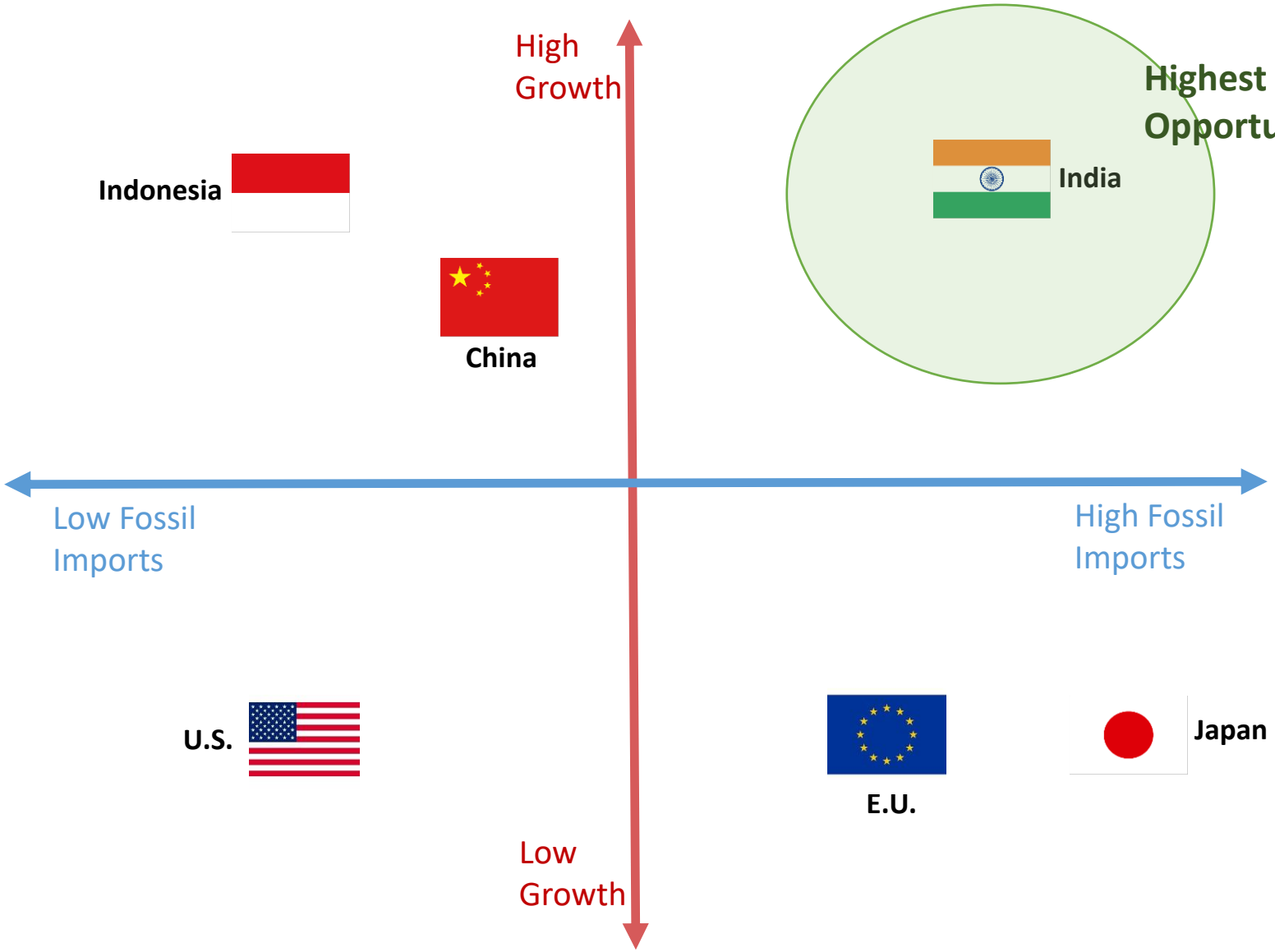
Resiliency

- Hedge against supply chain disruptions in the fuel sector
- RE+battery can be built faster to respond to demand growth

Industrial Competitiveness

- Auto sector is a major export driver and must remain competitive as the world rapidly adopts EVs

India has a unique opportunity to leapfrog to a cleaner energy future and align the political economy with clean energy transition.



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