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India’s path towards energy independence and a clean future: Harnessing india’s renewable edge for cost-effective energy independence by 2047

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Supplementary Information

India's Path towards Energy Independence and a Clean Future

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

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Methods and Data

Table 2 shows each scenario in detail.

Table 2: Details of Modeled Scenarios

Sector	Policy Lever	Reference Scenario	CLEAN-India
Power	% of carbon free electricity generation	• 23% in 2020 • 37% by 2030 (39% of native power demand; 350 GW of clean power) • 50% by 2040 • 60% by 2047	• 23% in 2020 • 46% by 2030 (50% of native power demand; 500 GW of clean power) • 80% by 2040 • 90% by 2047
	Appliance Energy Efficiency	• ~2-3% improvement per year 2020-2030 • ~1-2% improvement per year 2030-2040 • ~0.5-1% improvement per year 2040-2050	• ~4-6% improvement per year 2020-2030 • ~2-4% improvement per year 2030-2040 • ~1-2% improvement per year 2040-2050
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 • 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 • MDV/HDV: 20% by 2025, 80% by 2030, 100% by 2035
Industry	Electrified Production (% of total)	• Iron & Steel: 15% by 2050 • Cement: 0% by 2030, 15% by 2050	• Iron & Steel: 35% by 2050 • Cement:65% by 2050

		•	
	Green Hydrogen Based Production	• Iron & Steel: 0% by 2030, 5% by 2050 • Cement: 0% by 2030, 5% by 2050 • Fertilizers & Chemicals & Petrochemicals: 25% by 2050	• Iron & Steel: 10% by 2030, ~40% by 2040, 60% by 2050 • Cement: 15% by 2040, 25% by 2050 • Fertilizers, Petrochemicals & Chemicals: 50% by 2030, 100% by 2050
	Process and Material Efficiency	• Energy efficiency improvement: Steel (10% between 2020-2050), Cement (5% between 2020-2050), • Steel: Scrap ratio in recycling, i.e., secondary steel production, (~0.5by 2040-2050) • Improve Clinker to Cement ratio by 2% per decade	• Energy efficiency improvement: Steel (25% between 2020-2050), Cement (15% between 2020-2050), Fertilizers, Chemicals & Petrochemical (15% between 2020-2050) • Steel: Scrap ratio in recycling (0.65% by 2040,0.9 by 2050) • Improve Clinker to Cement ratio by 5% per decade • Demand Reduction/Material Efficiency: Cement 10%, Petrochemicals 50% • Captive Heat (Cement) by 2.5% by 2050

Carbon Capture, Utilization and Storage (CCUS) + Direct Air Capture (DAC)	Share of sectoral emissions	• Power: 0.5% CCUS by 2050 • Industry: 2.5% CCUS by 2050 • No DAC	• Power: 2% CCUS by 2050 • Industry: 5% CCUS by 2050 • Economy: 1% DAC by 2050

Power

As seen in the Table above, the Reference scenario models a pathway achieving 60% of carbon free electricity generation by 2047. In the CLEAN-India scenario, carbon free electricity generation reaches 90% by 2047. We model 90% clean grid (vs 100% clean) because studies have shown that the transition from 90% to 100% clean grid requires steep additional costs and technologies that are not currently commercially viable. We use PLEXOS,[1] an industry standard power system simulation software that conducts optimal capacity expansion and hourly system dispatch to assess a resource mix and hourly dispatch for each year between 2020 and 2050.[2] The model minimizes total generation cost (i.e., fixed plus variable costs) for the entire system, including existing and new generation capacity. We represent the Indian electricity grid using a single-node model, and do not model transmission.

For projecting the native (i.e., without any new transport or industrial electrification or green hydrogen production) electricity demand until 2037, we use state-level demand projections from Central Electricity Authority's (CEA) 19th and 20th Electric Power Surveys (EPS) (CEA, 2017 and 2022). Beyond 2037, we project the native electricity demand using historical growth rates. Additional electricity demand from transport and industrial electrification/hydrogen production is then added to the native electricity demand to estimate the aggregate national electricity demand for each year between 2020 and 2050. Hourly load pattern for the native electricity demand is estimated using actual load data for 2018 and our previous work on changing appliance and equipment penetration in India (Abhyankar et al, 2017). Hourly load patterns for electric vehicle charging are taken from Phadke et al (2016), Karali et al (2020), and Abhyankar et al (2022). Hourly load pattern for industrial electrification and green hydrogen production is taken as the average hourly heavy industrial load profile (largely flat throughout the day) based on our previous work (Karali et al, 2020).

Hourly wind generation profiles and hydro dispatch constraints are assessed using historical generation data (for the load-synchronized 2018 weather year). For solar, hourly generation profiles are developed using Global Horizontal Irradiance (GHI) or Direct Normal Irradiance (DNI) data for key sites within each state (Abhyankar et al., 2016). The scenario also incorporates coal capacity already under

[1] For more information on PLEXOS, see energyexemplar.com. PLEXOS uses deterministic or stochastic, mixed-integer optimization to minimize the cost of meeting load given physical (e.g., generator capacities, ramp rates, transmission limits) and economic (e.g., fuel prices, start-up costs, import/export limits) grid parameters.
[2] The fiscal year in India runs from April 1 through March 31. For example, FY 2030 runs from April 1, 2029 to March 31, 2030. In this report, we use the terms "fiscal year" and "year" interchangeably. Any reference to a year implies fiscal year unless specified otherwise.

construction per CEA annual progress reports: about 38 GW between 2021 and 2025, 23 GW until 2022, and 15 GW between 2023 and 2025 (CEA, 2021). The National Electricity Policy (NEP) stipulates that about 8 GW of existing coal capacity would retire by 2022, and about 25 GW by 2027; this includes plants that have surpassed their useful life and plants that are unable to meet required emission standards (CEA, 2018). For projecting clean technology costs, the scenario assumes cost reductions for solar and wind technologies over the next decade are half the observed historical rate, while Li-ion battery levelized cost of storage (LCOS) projections are based on previous bottom-up cost analysis (Deorah et al., 2020).[3] Between 2030 and 2040, clean technology cost reductions are assumed to continue at a 50% lower reduction rate (i.e. 25% of historical rate) and no cost reductions are assumed beyond 2040. Conventional fixed costs, fuel costs, plant-level variable costs, operational parameters, and cost of capital are based on Central Electricity Regulatory Commission (CERC) norms, and other Government of India (GoI) sources (e.g., MERIT website, reports under the RRAS mechanism, or state tariff orders).

Transport

The starting point for our analysis is calculating the Total Cost of Ownership (ECO) for EVs and Internal Combustion Engine (ICE) vehicles on a per-kilometer basis over the useful life of the vehicles. We calculate TCO for nine vehicle classes based on the number of wheels for light passenger vehicles (e.g. two-wheelers, three-wheelers, and cars) and gross vehicle weight for commercial vehicles. The TCO calculation includes the vehicle's upfront purchase price along with average maintenance and fuel costs. The EV TCO also includes the cost of public charging infrastructure and the cost of battery replacements if the vehicle's useful life is longer than that of the batteries; we assume a battery life of 10 years (approximately 3,000 full charge-discharge cycles). To model the dynamics of the nationwide vehicle fleet once EV sales targets are introduced, we use a custom vehicle stock turnover model – Faster Adoption of Clean Transportation (FACT). The FACT model estimates ICE vehicles and EVs retired per year using a survival function modeled separately by vehicle class. We estimate the total number of vehicles sold per year using historical sales data from the Ministry of Road Transport and Highways (MORTH, 2021). Annual vehicle sales are allocated between ICE vehicles and EVs based on the EV sales target for that year. Combining the vehicle-level TCO and the vehicle populations from the stock model, we arrive at total fleet-level costs per year.

As shown in table 1, we evaluate two scenarios: Reference scenario in which fleet electrification occurs according to market forces without new policy intervention, and a "CLEAN-India" scenario in which new policies are implemented and market forces shift to overcome barriers to EV adoption. Under the Reference scenario, by 2030, EVs make up about 23% of two-wheeler and three-wheeler sales, 15% of passenger car sales, and 7% of medium-duty and heavy-duty vehicle sales. By 2040, these numbers nearly double and increase to 60%, 30%, and 15%, respectively. Under the CLEAN-India scenario, EV sales increase logarithmically to 100% between 2020 and 2035, and by 2050, EVs make up 97% of all on-road vehicles. Our power sector module includes the impact of these goals on the reliability and functionality of the electric grid.

[3] Battery pack life is assumed to be 3,000 cycles, or 10 years. Project life is assumed to be 20 years, meaning that there will be one battery pack replacement in Year 11.

Industry

Our industrial energy model is a bottom-up energy-emissions model and consists of four main components: demand module, production module, capacity module, and energy and emissions module. It focuses on key heavy industries, including iron and steel, cement, fertilizers, and petrochemicals, which make up 80% of industrial energy consumption. We assume that the Reference Scenario continues to rely on coking coal and oil as fuel sources, while incorporating some green hydrogen and electrification into the energy processes associated with each sub-sector. In the reference scenario, electrified production is already very efficient, so efficiency measures are focused on BF-BOF and DRI processes. In the CLEAN-India Scenario, we assume that most of the hydrogen is used as a feedstock in fertilizers or other petrochemicals, and in hydrogen-based direct reduction processes in iron and steel production. Hydrogen is also assumed to be used in cement production to create high temperature heat, although some cement production is also assumed to be electrified. Most of the other low and medium heat applications are assumed to be electrified. Please refer to table 1 for details on scenario definitions and Appendix C for more detailed information about how the three sub-sectors were modeled.

The demand module forecasts the demand for various industrial products in India based on various sources, including the International Energy Agency (IEA) for steel, Bloomberg New Energy Finance (BNEF) for cement, and the Chemicals Petrochemicals Manufacturers Association (CPMA) for fertilizers, chemicals, and petrochemicals. The production module covers all existing and future production processes used in the production of industrial outputs, and models that total production must meet the demand (including exports) while conforming to scenario-specific constraints. The capacity module is a stock turnover model that models the existing capacity of production facilities, along with a forecast of their phase-out rate over time. New capacity needs are estimated based on annual demand, utilization of production capacity, production, and the retirement of existing production capacity, considering the median plant lifetime and a growth parameter. Finally, the energy and emissions module uses the energy/fuel and emissions intensity for each production process to estimate the total energy / fuel use and CO2 emissions. We detail the energy needed per ton of production output according to fuel type and track the use of each fuel in each production process within each sub-sector.

Power Sector Cost Assumptions:

Sector	**Key Parameter**	**2020**	**2030**	**2040**	**2050**
Power	Capital Cost $/kw by technology-Solar	**624**	**446**	**373**	**373**
Power	Capital Cost $/kw by technology-Wind (Onshore)	**950**	**927**	**881**	**881**
Power	Capital Cost $/kw by technology-Wind (Offshore)	**1948**	**1392**	**1134**	**1134**
Power	Capital Cost $/kw by technology-Coal	**1150**	**1150**	**1150**	**1150**
Power	Capital Cost $/kw by technology-Gas	**900**	**900**	**900**	**900**
Power	Capital Cost $/kw by technology-Hydro	**1500**	**1500**	**1500**	**1500**
Power	Capital Cost $/kw by technology-Nuclear	**2000**	**20000**	**2000**	**2000**
	Capital Cost	**900**	**520**	**400**	**400**

	$/kw by technology-Battery Storage (4-hr)				
Power	Capital Cost $/kw by technology-Coal variable cost (pithead power plants) (Rs/kWh)	**1.9**	**2.0**	**2.1**	**2.1**
Power	Capital Cost $/kw by technology-Coal variable cost (non-pithead plants) (Rs/kWh)	**2.5**	**2.7**	**2.9**	**2.9**
Power	Capital Cost $/kw by technology-Coal variable cost (imported coal) (Rs/kWh)	**2.8**	**3.0**	**3.2**	**3.2**
Power	Capital Cost $/kw by technology-Gas variable cost (domestic gas) (Rs/kWh)	**3.0**	**3.0**	**3.2**	**3.2**
Power	Capital Cost $/kw by technology-Gas variable cost (imported LNG) (Rs/kWh)	**4.0**	**4.5**	**5.0**	**5.0**

Transport Sector Cost Assumptions:

Sector	**Key Parameter**	**2020**	**2030**	**2040**	**2050**
Transport	Crude Oil price ($/bbl)	$70	$75	$85	$90
Transport	Gasoline Price ($/lit)	**1.3**	**1.6**	**1.8**	**1.8**
Transport	Diesel Price ($/lit)	**1.2**	**1.4**	**1.6**	**1.7**
Transport	ICE 2-W upfront vehicle price (USD/vehicle)	**$700**	**$700**	**$700**	**$700**
Transport	ICE 3-W upfront vehicle price (USD/vehicle)	**$1,500**	**$1,500**	**$1,500**	**$1,500**
Transport	ICE Passenger Cars upfront vehicle price (USD/vehicle)	**$8,800**	**$8,800**	**$8,800**	**$8,800**
Transport	ICE Light Commercial Vehicles (<3.5 T) upfront vehicle price (USD/vehicle)	**$15,000**	**$15,000**	**$15,000**	**$15,000**
Transport	ICE Heavy Commercial vehicles (3.5T-7.5T) upfront vehicle price (USD/vehicle)	**$17,430**	**$17,430**	**$17,430**	**$17,430**

Transport	ICE Heavy Commercial vehicles (7.5T-12T) upfront vehicle price (USD/vehicle)	**$19,000**	**$19,000**	**$19,000**	**$19,000**
Transport	ICE Heavy Commercial vehicles / Rigid Trucks (>12T) upfront vehicle price (USD/vehicle)	**$40,000**	**$40,000**	**$40,000**	**$40,000**
Transport	ICE Heavy Commercial vehicles / Tractor Trailers (>12T) upfront vehicle price (USD/vehicle)	**$50,537**	**$50,537**	**$50,537**	**$50,537**
Transport	ICE Bus upfront vehicle price (USD/vehicle)	**$69,180**	**$69,180**	**$69,180**	**$69,180**
Transport	EV2-W upfront vehicle price (USD/vehicle)	$1,500	**$853**	**$651**	**$588**
Transport	EV 3-W upfront vehicle price (USD/vehicle)	$3,214	**$1,869**	**$1,495**	**$1,390**
Transport	EV Passenger Cars upfront vehicle price (USD/vehicle)	$16,029	**$9,988**	**$8,305**	**$7,837**

Transport	EV Light Commercial Vehicles (<3.5 T) upfront vehicle price (USD/vehicle)	$32,143	**$18,151**	**$14,254**	**$13,169**
Transport	EV Heavy Commercial vehicles (3.5T-7.5T) upfront vehicle price (USD/vehicle)	$30,000	**$19,296**	**$16,315**	**$15,485**
Transport	EV Heavy Commercial vehicles (7.5T-12T) upfront vehicle price (USD/vehicle)	$51,000	**$26,130**	**$19,204**	**$17,275**
Transport	EV Heavy Commercial vehicles / Rigid Trucks (>12T) upfront vehicle price (USD/vehicle)	$101,000	**$52,660**	**$39,197**	**$35,447**
Transport	EV Heavy Commercial vehicles / Tractor Trailers (>12T) upfront vehicle price (USD/vehicle)	$158,750	**$73,382**	**$49,607**	**$42,985**
Transport	EV Bus upfront vehicle price (USD/vehicle)	$135,000	**$82,519**	**$67,903**	**$63,833**

Transport	ICE 2-W maintenance price (USD/km)	**$0.0065**	**$0.0078**	**$0.0092**	**$0.0105**
Transport	ICE 3-W maintenance price (USD/km)	**$0.0130**	**$0.0146**	**$0.0161**	**$0.0177**
Transport	ICE Passenger Cars maintenance price (USD/km)	**$0.0130**	**$0.0146**	**$0.0161**	**$0.0177**
Transport	ICE Light Commercial Vehicles (<3.5 T) maintenance price (USD/km)	**$0.0776**	**$0.0869**	**$0.0962**	**$0.1055**
Transport	ICE Heavy Commercial vehicles (3.5T-7.5T) maintenance price (USD/km)	**$0.1422**	**$0.1592**	**$0.1763**	**$0.1934**
Transport	ICE Heavy Commercial vehicles (7.5T-12T) maintenance price (USD/km)	**$0.1580**	**$0.1769**	**$0.1959**	**$0.2149**
Transport	ICE Heavy Commercial vehicles / Rigid Trucks	**$0.1950**	**$0.2184**	**$0.2419**	**$0.2653**

	(>12T) maintenance price (USD/km)				
Transport	ICE Heavy Commercial vehicles / Tractor Trailers (>12T) maintenance price (USD/km)	**$0.1755**	**$0.1966**	**$0.2177**	**$0.2388**
Transport	ICE Bus maintenance price (USD/km)	**$0.2969**	**$0.3578**	**$0.4186**	**$0.4795**
Transport	EV 2-W maintenance price (USD/km)	**$0.0033**	**$0.0039**	**$0.0046**	**$0.0052**
Transport	EV 3-W maintenance price (USD/km)	**$0.0065**	**$0.0073**	**$0.0081**	**$0.0088**
Transport	EV Passenger Cars maintenance price (USD/km)	**$0.0065**	**$0.0073**	**$0.0081**	**$0.0088**
Transport	EV Light Commercial Vehicles (<3.5 T) maintenance price (USD/km)	**$0.0388**	**$0.0434**	**$0.0481**	**$0.0528**

Transport	EV Heavy Commercial vehicles (3.5T-7.5T) maintenance price (USD/km)	**$0.0711**	**$0.0796**	**$0.0882**	**$0.0967**
Transport	EV Heavy Commercial vehicles (7.5T-12T) maintenance price (USD/km)	**$0.0790**	**$0.0885**	**$0.0980**	**$0.1074**
Transport	EV Heavy Commercial vehicles / Rigid Trucks (>12T) maintenance price (USD/km)	**$0.0975**	**$0.1092**	**$0.1209**	**$0.1326**
Transport	EV Heavy Commercial vehicles / Tractor Trailers (>12T) maintenance price (USD/km)	**$0.0878**	**$0.0983**	**$0.1088**	**$0.1194**
Transport	EV Bus maintenance price (USD/km)	**$0.0986**	**$0.1104**	**$0.1222**	**$0.1341**
Transport	EV charging infra costs ($/KW) (LDV)	**200**	**200**	**200**	**200**

Transport	EV charging infra costs ($/KW) (MDV/HDV)	**316**	**316**	**316**	**316**
Transport	Electric vehicle charging cost ($/kWh) - across vehicle classes	**$0.0775**	**$0.0775**	**$0.0775**	**$0.0775**
Transport	Battery pack replacement cost ($/kwh) - across vehicle classes	**N/A**	**$62**	**$50**	**$50**
Transport	2-W km/year	**7,000**	**7,000**	**7,000**	**7,000**
Transport	3-W km/year	**30,000**	**30,000**	**30,000**	**30,000**
Transport	Passenger Cars km/year	**12,000**	**12,000**	**12,000**	**12,000**
Transport	Light Commercial Vehicles (<3.5 T) km/year	**15,000**	**15,000**	**15,000**	**15,000**
Transport	Heavy Commercial vehicles (3.5T-7.5T) km/year	**35,000**	**35,000**	**35,000**	**35,000**
Transport	Heavy Commercial vehicles (7.5T-12T) km/year	**65,000**	**65,000**	**65,000**	**65,000**
Transport	Heavy Commercial vehicles /	**90,000**	**90,000**	**90,000**	**90,000**

	Rigid Trucks (>12T) km/year				
Transport	Heavy Commercial vehicles / Tractor Trailers (>12T) km/year	**120,000**	**120,000**	**120,000**	**120,000**
Transport	Bus km/year	**65,000**	**65,000**	**65,000**	**65,000**

Industry Assumptions

Iron and Steel

	Base year (2020)	Reference	CLEAN-India
Efficiency	Average process 'Energy Intensity' = ~26GJ/tonne steel	Improvement: 10% between 2020-2050	Improvement: 25% between 2020-2050
	'Scrap ratio' in Recycling (i.e., Scrap based EAF) = 0.45	0.45 by 2030 (same as 2020 level), 0.50 by 2040-2050	0.45 by 2030 (same as 2020 level), 0.65 by 2040, 0.90 by 2050
Electric production (% of total)	Mixed Scrap based EAF = ~28%	Mixed Scrap based EAF = ~28%	Mixed Scrap based EAF = ~28% by 2030 (same as 2020 level) ~25% by 2050
	'Electrolysis' = 0%	'Electrolysis' = 15% by 2050	'Electrolysis' = 35% by 2050
Green hydrogen-based production (% of total)	'DRI EAF (H2 based)' = 0%	'DRI EAF (H2 based)' = 0% by 2030, ~1% by 2040, ~5% by 2050	'DRI EAF (H2 based)' = 10% by 2030, 40% by 2040, 60% by 2050

CCUS application (% of total)	'SR BOF with CCUS' = 0%; 'BF BOF retrofitted with CCUS' = 0%; 'DRI EAF retrofitted with CCUS' = 0%	'SR BOF with CCUS' = 0% by 2030, ~1% by 2040, ~2.5% by 2050; 'BF BOF retrofitted with CCUS' = 0%; 'DRI EAF retrofitted with CCUS' = 0%	'SR BOF with CCUS' = 0% by 2030, ~1% by 2040, ~2.5% by 2050; 'BF BOF retrofitted with CCUS' = 0% by 2030, ~2% by 2040, ~2% by 2050; 'DRI EAF retrofitted with CCUS' = 0% by 2030, ~1% by 2040, ~1% by 2050
Rest of the production (% of total)	'BF BOF' = 42%; DRI EAF (coal+gas based) = 30%	'BF BOF' = ~47% by 2030, ~46% by 2040, ~42% by 2050; DRI EAF (coal+gas based) = ~27% by 2030, ~25% by 2040, ~20% by 2050	'BF BOF' = ~39% by 2030, ~19% by 2040, ~0% by 2050; DRI EAF (coal+gas based) = ~23% by 2030, ~12% by 2040, 0% by 2050

Cement

	Base year (2020)	Reference	CLEAN-India
Efficiency	Average process 'Thermal Energy Intensity' = ~3.15GJ/tonne clinker; 'Electricity Intensity' = ~80kWh/tonne cement	Thermal energy improvement: 1.5% by 2030, 3% by 2040, 6% by 2050; Electricity improvement: 1% by 2030, 2% by 2040, 3% by 2050	Thermal energy improvement: 4% by 2030, 8% by 2040, 15% by 2050; Electricity improvement: 3% by 2030, 5% by 2040, 8% by 2050
	‘Clinker to cement ratio' = 0.73	0.71 by 2030, 0.68 by 2040, 0.66 by 2050	0.69 by 2030, 0.64 by 2040, 0.60 by 2050
Electrified production (% of total)	'Electric rotary kiln' = 0%	'Electric rotary kiln' = 0% by 2030, 15% by 2050	‘Electric rotary kiln' = 65% by 2050

Green hydrogen-based production (% of total)	'H2 rotary kiln' = 0%	'H2 rotary kiln' = 0% by 2030, ~2% by 2040, 5% by 2050	'H2 rotary kiln' = 1% by 2030, 15% by 2040, 25% by 2050
CCUS application (% of total)	'Conventional rotary kiln with CCUS' = 0%	'Conventional rotary kiln with CCUS' = 0% by 2030, ~0.5% by 2040, ~2.5% by 2050	'Conventional rotary kiln with CCUS' = 0% by 2030, ~2.5% by 2040, ~5% by 2050
Captive heat-based production (% of total)	'Captive heat-based rotary kiln' = 0%	'Captive heat-based rotary kiln' = 0% by 2030, ~0% by 2040, ~1% by 2050	'Captive heat-based rotary kiln' = 0% by 2030, ~0.5% by 2040, ~2.5% by 2050
Rest of the production (% of total)	'Conventional rotary kiln' = 100%	'Conventional rotary kiln' = ~100% by 2030, ~97% by 2040, ~75% by 2050	'Conventional rotary kiln' = ~99% by 2030, ~45% by 2040, ~0% by 2050

Chemicals, Petrochemicals, and Fertilizers

	Base year (2020)	Reference	CLEAN-India
Efficiency	Average process 'Energy Intensity' = 18.5GJ/tonne fertilizer; 15.8GJ/tonne chemical and petrochemical output	No Improvement	Improvement: 2% by 2030, 4% by 2040; 15% by 2050
Green hydrogen-based production (% of total)	'H2-fired heaters' = 0%	'H2-fired heaters' = 'PC, C&F': 0% by 2030, 25% by 2050	'H2-fired heaters' = 'PC, C, &F': 50% by 2030, 100% by 2050
Demand Reduction in Petrochemicals (e.g. due to material substitution, recycling, elimination etc.)	**Demand Reduction** = 0%	No Demand Reduction	Demand Reduction' = 3% by 2030, ~25% by 2040, ~50% by 2050

Rest of the production (% of total)	'Conventional crackers' = 100%	'Conventional crackers' = 'PC, C, , &F': 99% by 2030, 85% by 2040, 75% by 2050	'Conventional crackers' = 'PC, C’:': ~70% by 2030, 0% by 2040 // 'F': 60% by 2030, 0% by 2040

Cross Sectoral Assumptions

Sector	**Key Parameter**	**2020**	**2030**	**2040**	**2050**
Cross-sectoral	Imported Coal Price ($/ton)	96	70	70	70
Cross-sectoral	Interest Rate (%)	8%	8%	8%	8%
Cross-sectoral	Real Discount rate (%)	3%	3%	3%	3%
Cross-sectoral	Rupees/Dollar	75	75	75	75
Environmental Benefits	Premature deaths per kWh of coal based power generation (without PCT)	78.4	78.4	78.4	78.4
Environmental Benefits	Premature deaths per kWh of coal based power generation (with PCT)	56.15	56.15	56.15	56.15

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