पेट्रोलियम एवं
प्राकृतिक गैस मंत्रालय
MINISTRY OF
PETROLEUM AND NATURAL GAS

सत्यमेव जयते

THE GREEN SHIFT

The low carbon transition of India's Oil & Gas sector

Final Report

Energy Transition Advisory Committee
Ministry of Petroleum & Natural Gas
Government of India

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This report has been compiled by the Energy Transition Advisory Committee (ETAC), formed under the direction of the Ministry of Petroleum & Natural Gas (MoP&NG) to draw an energy transition pathway for Oil & Gas Public Sector Undertakings in the country. The report is focuses on increasing adoption of clean energy solutions such as hydrogen, biofuel, nuclear, geothermal, tidal in the energy mix of the country.

About the Committee

The Committee was constituted under the leadership of Sh. Tarun Kapoor, ex-Secretary, MoP&NG, who has been instrumental in bringing together the industry knowledge, net zero understanding of various consultancy groups and the national priorities, along with his own guidance in developing this report. With Sh. Tarun Kapoor taking charge as an Advisor to the Hon'ble Prime Minister, the onus of concluding the report was shouldered by Sh. Subhash Kumar, ex-Chairman, ONGC. The committee constituted of the following members:

Committee Member	Designation	Company / Organisation
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Mr. Subhash Kumar	Ex-Chairman	ONGC
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Subject Matter Experts

The report would not be possible without the subject matter expertise provided by leading consultancies & recognized organisations like Bp, ACME, ICRA, AT Keraney, Ernst & Young, Pricewaterhouse Coopers, KPMG, Accenture, Praj Industries, Technimont, RIL, SIAM, SNAM, Greenko, IEA and BEE. The Committee would like to specially thank the Boston Consultancy Group and McKinsey & Company for their support and immense contribution in developing this report. The content of presented in this report draws inputs from the presentations made by these subject matter experts on various aspects of decarbonisation and energy transition.

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THE GREEN SHIFT

Ministry of Petroleum & Natural Gas,
Government of India,
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February 2023

MESSAGE BY CHAIRMAN

Tarun Kapoor
Chairman,
Energy Transition Advisory Committee (ETAC),
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India made the historic announcement of reaching Net Zero by the year 2070. As the third largest aggregate emitter in the world, this announcement can prove to have a significant impact on the global fight against climate change. India's commitment marks a significant boost for low-carbon energy and is a directional shift in the fossil fuel business. As India moves at pace on its growth trajectory, the country is resolute on putting across a unique approach to energy usage for bridging the past and the future.

India has been at the forefront of global growth over the past two decades and will remain a key driver of global growth in the coming decades. Fossil fuels have been the bedrock of fuelling India's growth story. With significantly low per capita energy use and issues still persisting in ensuring reliable coverage and availability across the country, the nation's focus has always been towards ensuring an energy paradigm of safe, secure, sustainable and affordable round-the-clock access and availability. Increased energy usage globally, as in India's case, has led to an increase in emissions; however, India’s per capita emissions are near the bottom of global emitters. If one accounts for historical emissions, Indian per capita contributions also remain significantly low. With projected growth in population and demand, India’s energy needs are bound to grow over the coming decades. As the country moves towards securing a Net Zero future, besides focusing on energy conservation and reduction in energy intensity of the economy, most of India's growth in energy demand would have to be met by harnessing the potential of low-carbon energy sources. The scale of transformation required is massive.

The important factors which will define India's energy transition roadmap are as follows:

- India cannot continue to depend on large-scale energy imports and must develop its own resources.
- India has to move towards cleaner energy sources progressively and cannot afford high pollution levels.
- The affordability of energy will always remain an important issue.
- India's primary energy sources are coal, oil, natural gas, renewable and nuclear. Untreated biomass is another source of energy, but its usage is declining. Coal is the primary energy source for producing grid electricity and is used by heavy industries like steel & cement. While coal is available in India, oil & gas reserves of similar magnitude are yet to be discovered in the country.
- India has huge potential for solar energy, and the cost of solar power has come down. There is a limit to which solar can be pushed into the grid, considering the fact that the cost of storage remains high.

- Grid power contributes only 18% of the total energy consumed, which will have to go up.
- The world is waiting for breakthroughs in specific areas like storage, reduction in the cost of producing and storing hydrogen and biological pathways for energy production from various types of waste.

The wheels of decarbonisation are already set in motion. India has set ambitious targets for renewable energy, emphasizing energy efficiency, promoting electric vehicles, setting up a national carbon market, building a waste-to-fuel economy, and pursuing innovations through schemes like 'Atmanirbhar Bharat', amongst many others. Many aspects regarding the availability, reliability, cost and utility of low-carbon fuels would need to be addressed to achieve the net-zero targets.

This report mainly deals with energy transition issues connected with the oil and gas sector, and energy transition will also significantly impact other sectors like industry, transport, cooking etc. In India, we have large Public Sector Undertakings and some private companies which control most of the energy sector, be it power, coal or oil and gas. These large companies, primarily PSUs, need to transition to cleaner energy sources. The existing oil and gas majors have a good network all over the country, with suitable infrastructural might and financial strength. Therefore, if these companies take the lead in India's energy transition, the task would be much easier. Most companies have already taken steps in the right direction.

I am thankful to the Ministry of Petroleum and Natural Gas, particularly Minister Shri Hardeep Singh Puri, for setting up the Energy Transition Task Force to look at the important issue of the energy transition. The Task Force invited experts from India and abroad for their input and had several meetings to understand the subject. I am also grateful to Indian Oil Corporation for providing secretarial assistance and support. The Taskforce was fully supported by McKinsey and BCG in putting together the present report, for which the Task Force is thankful. We hope that this report will help shape the Indian Energy Transition Roadmap.

(Tarun Kapoor)
Chairman, Energy Transition Advisory Committee

FOREWARD

Subhash Kumar
Member and Nodal Officer,
Energy Transition Advisory Committee
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The energy transition is the hot topic of the day. Daily, multiple studies and reports are being churned out on the subject. The positive side of incessant coverage is that the issue is getting the focus and attention it deserves. The world does need to transition to cleaner ways of doing things through an orderly and affordable transition. Definite standard templates for the inflow of huge investments required for a smooth and orderly transition and access to technologies needed to achieve the end state do not exist today. Additionally, as the world transitions towards an energy system characterised by the inherent intermittency of renewables, there is a need to have a layered energy supply with conventional energy sources, with fossil fuel-based energy still as the backbone of energy systems. The world will also need to master harnessing the full potential of bio-based endowments. The multiplicity of energy supply lines will require redundancies which will involve huge costs. The issue will get addressed over time till renewables and bio-based energy become the mainstream source.

Reducing investments in the fossil fuels value chain (both upstream-downstream) in the aftermath of the bloodbath that the sector faced during COVID and, more recently, due to ongoing geopolitical crises, have disrupted fossil fuel supplies at affordable prices. It is counterintuitive that near-record investible surpluses generated by the fossil fuel companies are not flowing back into the sector – possibly due to the lack of belief in long-term sustainable business models. Assuming the current trend builds up, it could mean that the world would have enough oil and gas reserves to be produced, and there will be enough demand. Yet, given the perception of the ever-shortening time horizon over which these investments need to be in money, further investment in the fossil fuel value chain may dry up globally. All this does not bode well for an orderly, smooth, painless transition.

India needs to have a unique armoury of solutions, referring to global best practices, building on local peculiarities to deal with the enormous challenges that will be faced for a turbulence-free orderly transition. The Indian approach to use this challenge to convert it into opportunity through targeted policies, like Production Linked Incentives, emphasis on reducing energy dependence, employment generation and thus strengthening the economy, building on its young aspiring technology-savvy population, robust institutional framework and Govt willing to lead from the front, have potential to enable India to play a leading role in helping the world traverse this challenging journey.

Several entities and individuals, some of whom have been identified in the report, made presentations to the committee. ETAC was ably supported by BCG and Mckinsey. These interactions provided critical inputs and supported ETAC over the last several months. Various organisations, specifically Oil PSU teams, have worked hard to finalise the report and have provided vital inputs. The report also draws on information from various other sources. These inputs have helped the team to paraphrase the report, and its recommendations, and as such, the contribution of all named and unnamed sources, is acknowledged.

It was a matter of pride for me to have the opportunity to work as part of the ETAC. Over the past few months, ETAC, under the leadership of Mr Tarun Kapoor, Ex-Secretary to Govt of India and now Advisor to Hon Prime Minister. ETAC had extensive deliberations on the issues concerning energy transition with many stakeholders, including Ministries, PSUs, private sector players, banks, technology providers etc. I believe the resultant report deals with broad areas, segments, and the roles key stakeholders need to play for an orderly energy transition. Any exercise of this nature cannot answer problems that may arise along this journey. Hopefully, the report will serve as a reference to build on and probe individual subjects and issues related thereto in greater detail, to come up with what could serve as a good way forward when planning for specifics. Indian track record on its commitments and delivery against the same has been impressive.

Deliberations during the recently held CoP 27 and World Economic Forum raise hope of globally coordinated efforts towards a smooth transition. It is anticipated that the global narrative on transition will undergo a transformative change during the Indian presidency of G20. Recent energy witnessed at Indian Auto Expo was the testimony of the Govt., industry and other stakeholders all working together to raise hope that the transition to green can be less turbulent if all stakeholders work in unison. But as is normal, in a case where we have an idea of the desired end state but no clue as to how exactly it will happen, there will be situations of occasional hurras and setbacks involving regretted moves. India is uniquely positioned to lead the world through this challenge, and it is hoped that the deliberations at the forthcoming India Energy Week will pave the way for working on specific agendas and plans across main sectors to usher into a green world.

Mr Tarun Kapoor, Chairman of the Committee, has been a constant source of guidance with his thorough understanding of complicated issues, capacity to see through the green lights, spot solutions and amazing time management, for which the team remains deeply indebted. I feel privileged to have got the opportunity to have been part of all this. My special appreciation to the MOPNG, IOCL & ONGC management for their excellent support. I express my gratitude to Indian Oil's Alternate Energy and Sustainable Development Group (under Planning & Business Development) for their whole-hearted support and work in organising the committee meetings and development of the report.

(Subhash Kumar)
Energy Transition Advisory Committee

India is the front-runner in mitigating climate change globally and is progressing fast on its energy transition agenda. The country is willing to innovate to keep its pledge of protecting the environment while simultaneously addressing the growing demand for energy.

Shri Hardeep Singh Puri,
Hon'ble Minister,
Ministry of Petroleum & Natural Gas

Photo Credit: Adobe Stock

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ABBREVIATIONS USED

A&N	Andaman & Nicobar
AEM	Anion Exchange Membrane
AFID	Alternative Fuel Infrastructure Directive
AFIR	Alternative Fuels Infrastructure Regulation
APM	Administrative Price Mechanism
ATF	Aviation Turbine Fuel
ATJ	Alcohol To Jet
BAU	Business As Usual
BEV	Battery Electric Vehicle
BPCL	Bharat Petroleum Corporation Limited
CAGR	Compound Annual Growth Rate
CBG	Compressed BioGas
CCEA	Cabinet Committee on Economic Affairs
CCS	Carbon Capture and Storage
CCUS	Carbon Capture Utilization and Sequestration
CDU	Crude Distillation Unit
CEF	CORSIA Eligible Fuel
CEMILAC	Centre for Military Airworthiness and Certification
CGD	City Gas Distribution
CHC	Custom Hiring Centre
CIS	Commonwealth Independent States
CMP	Comprehensive Mobility Plan
CNG	Compressed Natural Gas
COP	Conference of the Parties
CORSIA	Carbon Offsetting and Reduction Scheme for International Aviation
CPSU	Central Public Sector Undertaking
CSIR-IIP	Council of Scientific and Industrial Research–Indian Institute of Petroleum
CSP	Concentrated Solar Power
CVs	Commercial Vehicles
DFC	Dedicated Freight Corridor
DFPD	Department of Food and Public Distribution
DFS	Department of Financial Services
DGCA	Directorate General of Civil Aviation
DME	DiMethyl Ether
E&P	Exploration & Production
EBP	Ethanol Blended Petrol
EIL	Engineers India Limited
EOI	Expression of Interest
EOR	Enhanced Oil Recovery
ESG	Environmental Social and Governance
ETS	Emissions Trading System
EU	European Union
EV	Electric Vehicle
EVSE	Electric Vehicle Supply Equipment
FAME	Faster Adoption and Manufacturing of Electric and Hybrid Vehicles scheme
FCI	Food Corporation of India
FCV	Fuel Cell Vehicle
FOM	Fermented Organic Manure
FPO	Farmer Producer Organizations
FSSAI	Food Safety & Standards Authority of India
GA	Geographical Area
GAIL	Gas Authority of India Limited
GDP	Gross Domestic Product
GHG	Green House Gas
$GtCO_2e$	Gigatonnes of CO_2 equivalent
HCV	Heavy Commercial Vehicle
HDV	Heavy Duty Vehicle
HEFA	Hydro-processed Esters and Fatty Acids
HPCL	Hindustan Petroleum Corporation Limited
HSD	High Speed Diesel
ICAO	International Civil Aviation Organization
ICE	Internal Combustion Engine
ICM	Indian Carbon Market
ICP	Internal Carbon Pricing
IEA	International Energy Agency
IIoT	Industrial Internet of Things
IMF	International Monetary Fund
IMO	International Maritime Organization
IOCL	Indian Oil Corporation Limited
IOCs	International Oil Companies

IPCC	Intergovernmental Panel on Climate Change
IR	Indian Railways
ISMA	Indian Sugar Mills Association
KLPD	Kilo Litre Per Day
KPI	Key Performance Indicator
kWhr	Kilowatt Hour
LCFS	Low Carbon Fuel Standards
LCV	Light Commercial Vehicle
LDV	Light Duty Vehicle
LFOM	Liquid Fermented Organic Manure
LNG	Liquefied natural gas
LOHC	Liquid Organic Hydrogen Carriers
LOI	Letter of Intent
LPG	Liquefied Petroleum Gas
MCX	Multi Commodity Exchange
MEPC	Marine Environment Protection Committee
MMSCMD	Million Metric Standard Cubic Meters per Day
MNRE	Ministry of New and Renewable Energy
MoEFCC	Ministry of Environment, Forest and Climate Change
MoPNG	Ministry of Petroleum and Natural Gas
MS	Motor Spirit
MSME	Micro, Small and Medium Enterprise
MSW	Municipal Solid Waste
MWP	Minimum Work Program
NDC	Nationally Determined Contribution
NG	Natural Gas
NOCs	National Oil Companies
O&G	Oil and Gas
OECD	Organization for Economic Co-operation and Development
OEM	Original Equipment Manufacturers
OGMC	Oil and Gas Marketing Company
OIL	Oil India Limited
OMC	Oil Marketing Company
ONGC	Oil & Natural Gas Corporation
PAT	Perform Achieve and Trade scheme
PE	Private Equity
PEM	Proton Exchange Membrane
PESO	Petroleum and Explosives Safety Organization
PLI	Production-Linked Incentive
PMUY	Pradhan Mantri Ujjwala Yojana
PNG	Piped Natural Gas
PNGRB	Petroleum and Natural Gas Regulatory Board
PROM	Phosphate Rich Organic Manure
PtL	Power to liquids
REC	Renewable Energy Certificates
RED	Renewable Energy Directive
REDD+	Reducing Emissions from Deforestation and forest Degradation
RRT	Regional Rapid Transport
RSB	Roundtable on Sustainable Biomaterials
RUCO	Repurpose Used Cooking Oil
SAF	Sustainable Aviation Fuel
SATAT	Sustainable Alternative Towards Affordable Transportation
SDG	Sustainable Development Goal
SDS	Sustainable Development Scenario
SIAM	Society of Indian Automobile Manufacturers
SMBA	Simulated Moving Bed Absorption
SMR	Steam Methane Reforming
SOEC	Solid Oxides Electrolyzer Cell
SPV	Special Purpose Vehicles
STCH	Solar ThermoCHemical
STEPS	Stated Policies Scenario
TBO	Tree Borne Oil
TCO	Total Cost of Ownership
UCO	Used Cooking Oil
UGS	Underground Storage Reserves
UN	United Nations
VC	Venture Capital
VCM	Voluntary Carbon Markets
VDU	Vacuum Distillation Unit
WEF	World Economic Forum
ZEV	Zero Emission Vehicle

Chapter i

PREFACE

PREFACE

THE CLIMATE CONTEXT[1]

Based on the current policy pathway defined by countries worldwide, the earth is expected to be 2.7-3.5°C warmer than pre-industrial temperature levels by the end of this century. The European Union, United States, and China, contributing more than 50 percent of global CO_2 emissions, have set their aspirations to become climate neutral by 2050 to 2060. However, these policies would still lead to a temperature increase of more than 2°C & 4°C, respectively, which is not in line with the CoP 21 target of keeping temperature well below 2°C compared to pre-industrial levels and preferably to 1.5°C pathway.

To successfully meet this target for limiting global warming, it is crucial to reduce GHG emissions in the next eight years by around 50 percent, in addition to other actions, such as expanding renewable energy, decarbonizing the transport and industrial sectors, rapidly phasing out coal, and investing in carbon removal.

Over 2,200 companies have committed to science-based targets, and twice as many have taken decarbonization action. In addition, climate commitments made by a majority of the top 20 companies in steel, aviation, vehicle OEMs, oil & gas, and chemicals sectors address over 85% of their combined production, thus accelerating the energy transition.

The role of electricity in the final consumption mix is expected to grow from approximately 20 percent today to more than double by 2050. As most projections suggest, total fossil fuel demand is projected to peak before 2030 and is expected to drop by 40 percent by 2050 when it will make up only 43 percent of global energy demand. Globally, renewables are projected to dominate the power generation mix, reaching up to 80 - 90 percent in 2050. However, given the different starting points from which various nations are commencing their transition journey, the trends around energy usage and the role to be played by different energy sources could see diverging trends.

In India, MS and HSD demand are expected to peak in 2040 and are projected to decline thereafter due to the electrification of vehicles. LPG demand is expected to decline after 2030, ceding ground to PNG for which massive CGD grid expansion is underway, and then electrification of cooking and reduce to zero by 2070. Aviation fuel demand is expected to continue to grow at 3.5% CAGR but will be gradually substituted by SAF (50% blending by 2070) due to CORSIA mandates. Naphtha demand is expected to rise at 4.5% CAGR (2030-50) and 2.3% CAGR (2050-70) because of increasing demand for petrochemicals. However, effective demand may be lower because of increased recycling activity. However, the consumption and demand growth trends for fossil fuel-based energy products in India will differ from global trends for at least another 15 to 20 years. The transition journey is the function of the low level of current per capita energy consumption, which is about one-third of global per capita energy intake, and need for more energy intake as Indian economy clocks high growth rates over coming decades to sustain improving standards of living in the country.

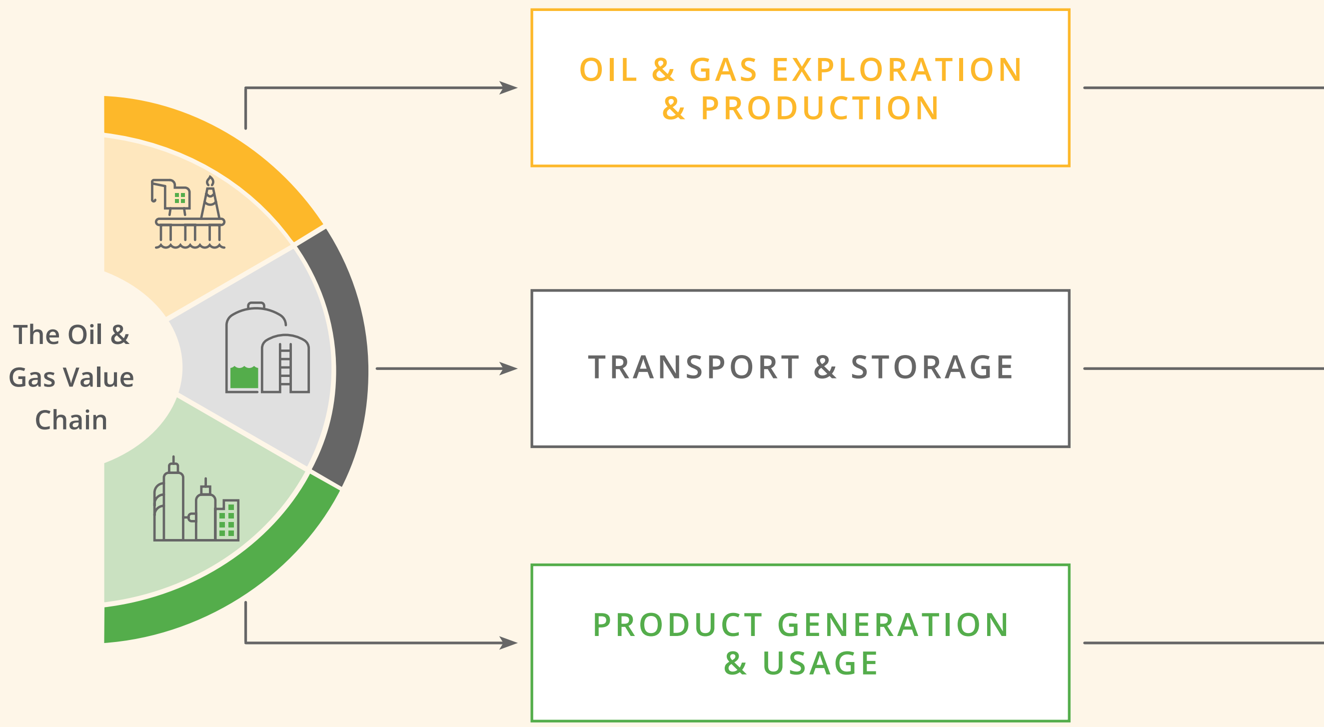
Globally as well as for India, the rate of transition in fossil fuel consumption primarily depends on the shift in the auto sector to EVs. As of date, India has a crude refining capacity of About 260 MMT. During the year 2021-22, India imported 42 MMT of Petroleum products and at the same time exported about 63 MMT of products. For a country like India which is about 85% import-dependent for crude, having 100% coverage with a sufficient safety factor is critical in respect of refinery capacity for India, as surplus refining capacity is a hedge against the situation of product shortages.

Having achieved the target of 10% EBP in May 2022, India has preponed target of achieving 20% ethanol blending and 5% biodiesel blending, by the year 2025 and 2030, respectively. Consistent with global trends, India is also witnessing early signs of transition towards EVs on the back of policy mandates. However, as the issues related to battery technology and range anxiety of EVs are expected to get addressed over the next two to three years, the off-take of diesel and petrol may not sustain its growth trajectory.

Additionally, railways being a safer and greener mode of transport, will garner a higher share in passenger and freight traffic over time. India's strategic refinery expansions could see a change, especially with the rise in petrochemical demand.

Due to declining costs, most of the growth in renewables is expected to come from solar and onshore wind. This trend of lowering costs is expected to continue, resulting in faster adoption of renewables and an accelerated transition from conventional fossil fuels. As renewable sources deliver green energy at significantly lower prices than fossil-fuel-based energy, the Government's policy support for the sector has exhibited significant success. These supply sources will be critical suppliers of incremental energy and economic development. Through well-targeted PLI schemes, introduced by the government recently, the domestic capacity in technology and related equipment & hardware has increased. This has helped in building leadership positions. As the world speeds along its transition journey, the intermittency issue is likely to get addressed with renewables through *round-the-clock* power on the back of advancements in battery storage technology, pumped hydro and upgraded intelligent electricity grids. Some of these areas will serve as high-investment and innovation areas requiring sustained focus & support.

The Oil & Gas Value Chain



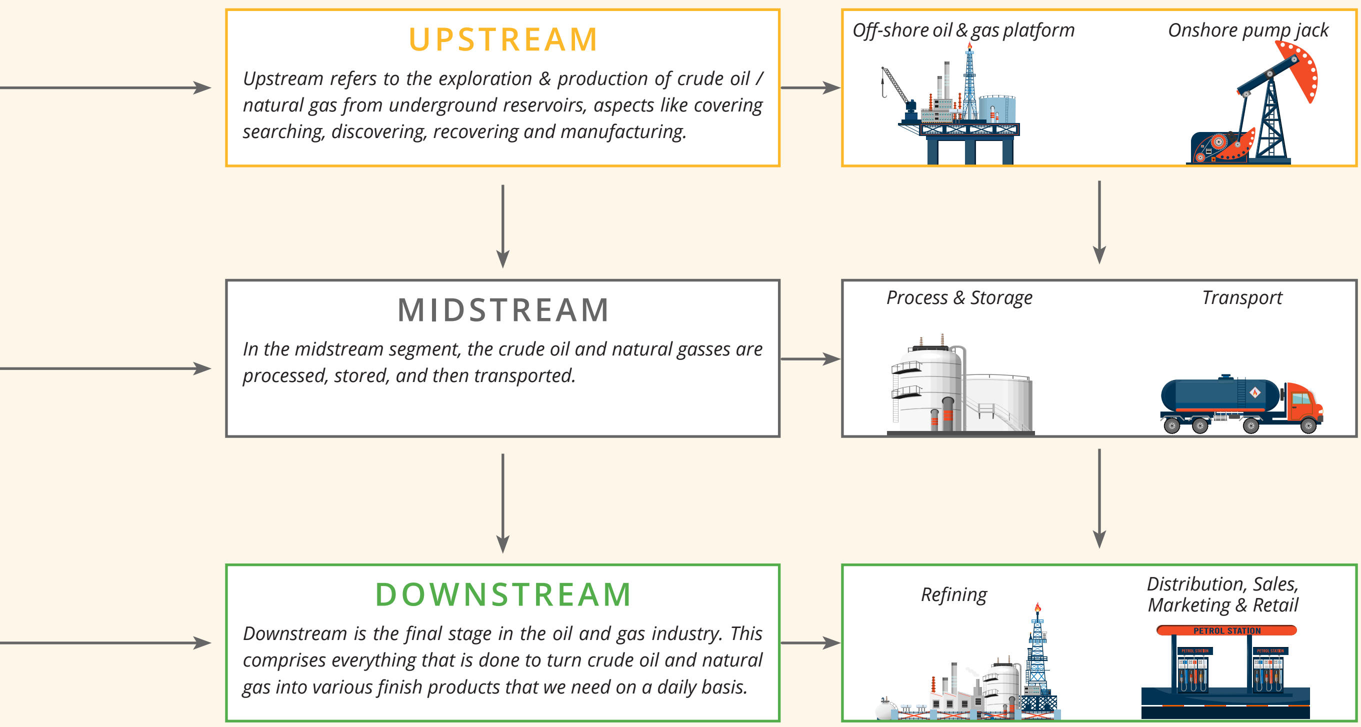
[1] *IEA 2021 India Energy Outlook*

THE INDIAN OIL & GAS INDUSTRY LANDSCAPE[2]

The oil and gas sector is a key prime mover for the Indian economy, influencing the country's energy transition-related decision-making process. India has become a $3 trillion economy and is likely to become a $5 trillion by 2026-27. This growth is essentially fuelled by increased consumption of energy. Unfortunately, this also entails an increase in hydrocarbon emissions. Hence, India has to increase its energy supply in a sustainable manner that does not result in huge increase in the emissions.

On the energy supply side, India has 23 refineries, 18 of which are public, two of which are joint, and three of which are private. Refineries in the public sector processed 138.08 MMT of crude oil in FY 22, up 1.65% from 108.03 MMT in FY 17. On the other hand, the throughput of crude oil in private-sector refineries increased at a CAGR of 6.27% from 33.43 MMT to 83.18 MMT at the same time.

In 2017, the government mandated the refineries to deliver Bharat Stage VI (equivalent to Euro Stage VI) automotive fuels from April 2020, a jump from Bharat Stage IV standard fuels prevalent at that time. The refineries have upgraded their facilities to comply and have been able to ensure BS-VI standard fuels across all states.



[2] IBEF, September 2022

INDIA'S OIL & GAS INDUSTRY: A SNAPSHOT

~30 MMT
Domestic crude oil production

~200 MMT
Domestic consumption of petroleum products

~250 MMT
Domestic petroleum product production

~34k MMSCM
Gross Natural Gas production

Source: Snapshot of India's Oil & Gas data - Oct, 2022, Petroleum Planning and Analysis Cell (PPAC), Ministry of Petroleum & Natural Gas, GoI

~64k MMSCM
Annual Natural Gas consumption

~115 BILLION $
Net import of Oil & Gas products

86 PERCENT
Crude oil import dependency*

** on POL consumption basis*

~24 PERCENT
Petroleum product import to India's gross imports**

*** in value terms*

Photo Credit: Adobe Stock

THE LOW CARBON OIL & GAS TRANSITION

The oil & gas sector is likely to be significantly disrupted by climate change and changing stakeholder expectations. The industry must reorient its business model to develop capability and capitalize on emerging opportunities around energy transition and net zero. The sector needs to adapt and pursue businesses in new areas like CCUS, Biofuels, Hydrogen, Energy Efficiency etc. The companies will be better placed to capitalize on the emerging business opportunities within the overall energy domain based on adjacency criteria to continue growing their businesses as the country transitions for the benefit of all the stakeholders.

The oil & gas sector entities in the public and private sectors are aware of the global developments around energy transition and net zero. Many Indian companies are developing ESG & energy transition targets and starting to pursue opportunities around low-carbon energy opportunities. Also, ESG has become a critical statutory requirement with SEBI's introduction of Business Responsibility Sustainability Reporting. As companies' core competencies are strengthened around energy transition and ESG, the sector's efforts on energy transition would gain traction in the country and enable oil & gas companies to minimize emerging risks associated with the fossil fuel business.

Energy transition has been taking place over the years. From a world overwhelmingly dependent on bio-based energy, the Industrial revolution was fuelled by a coal-driven energy supply. During the 20th century, oil and gas upstaged coal as a dominant source of energy supply. Humanity's growth and prosperity have been directly dependent on the improved energy supply value chain. Unfortunately, in the process, humanity has already exhausted nearly 75% of the carbon budget, and now it faces the spectre of self-inflicted disasters. In this context, new found urgency and seriousness augur well to bring the issue of climate to centre stage, and it is critical that from now on, the policies and businesses are driven by factoring in the centrality of the need to transition to net zero at the earliest possible. With its demonstrated credentials to back the talk with actions, India is poised to play a critical role in the global energy transition. From this perspective, in the year of India's G-20 Presidency, it is expected that the reports like this will help trigger follow-up actions to meet the country's goals for a smooth, orderly and just energy transition.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Chapter

1

THE GLOBAL ENERGY TRANSITION SCENARIO

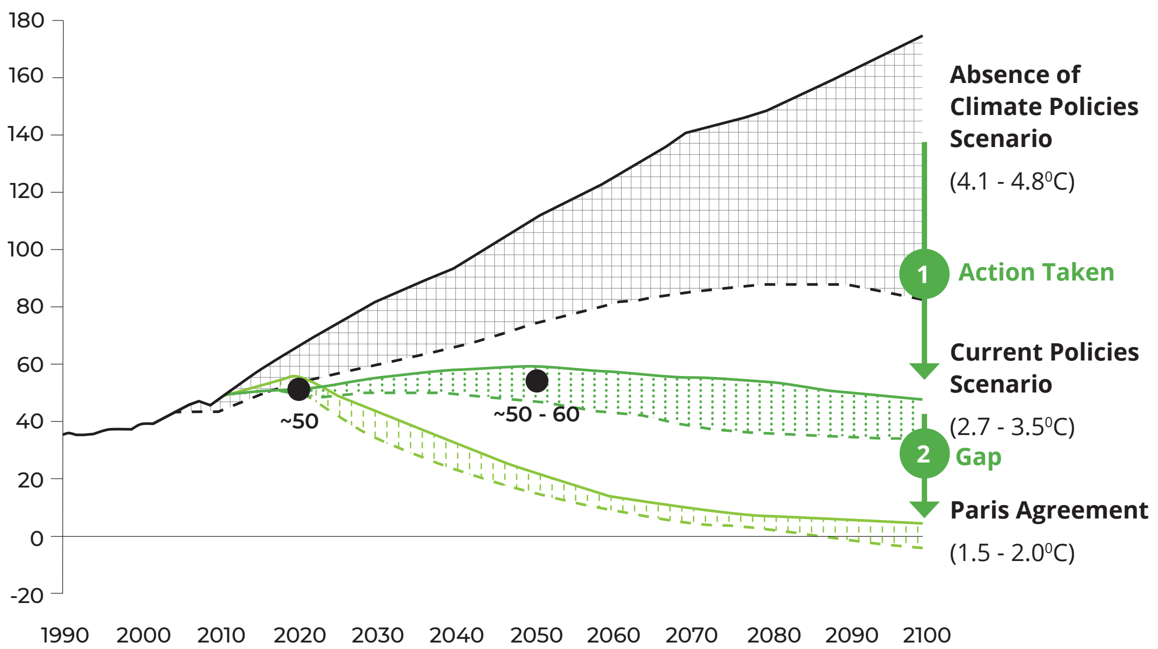
In this section

THE GLOBAL ENERGY TRANSITION SCENARIO

GLOBAL ACTION ON CLIMATE CHANGE

Since 1995, when the very first Conference of the Parties (COP) took place in Berlin to forge international cooperation to combat climate change, the issue of climate change has transformed from a fringe topic to a global priority. 197 countries signed the Paris Agreement at the 2015 conference, committing to limit the global temperature increase to below 2°C. Six years later, at the UN Climate Change Conference in 2021 in Glasgow (COP 26), there was commitment and momentum toward attaining this goal, but those pledges will only limit global warming to 2.4°C. At this point, a 1.5°C pathway seems like a mirage in the rapidly warming world around us. The build-up has continued through COP 27.

Exhibit-1.1: Annual GHG emissions and expected global warming, $GtCO_2$ equivalent



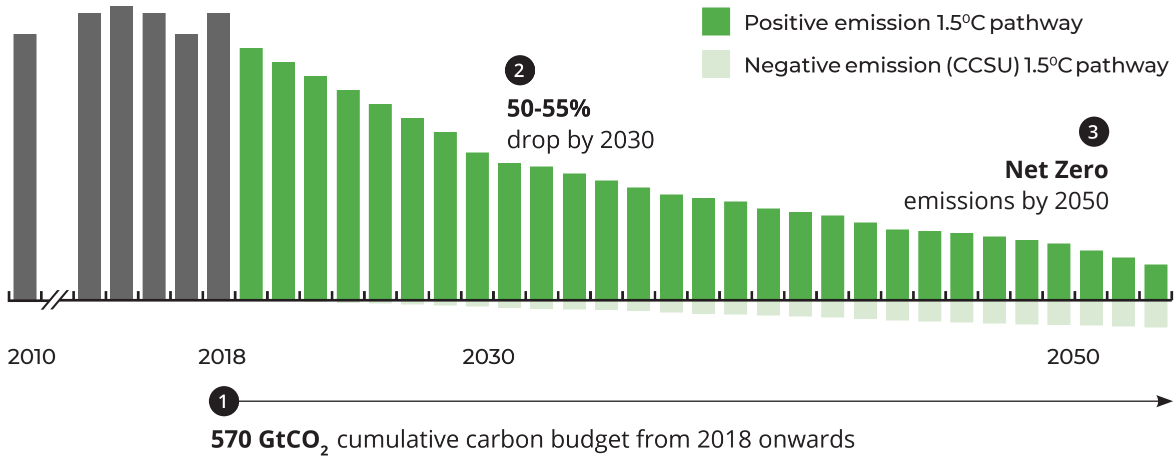
Source: Paris Agreement; Climate Action Tracker; Intergovernmental Panel on Climate Change

The Emissions Gap Report 2021, an annual report that shows the gap between actual greenhouse gas (GHG) emission levels and the levels required to combat climate change, points out that all of the current national climate pledges and other mitigation efforts will still set the world on the path to a global temperature rise of 2.7°C by the end of this century. The only way to keep the world on the 1.5°C pathway is by halving GHG emissions in the next eight years.[1]

Alongside the current policies set out by various governments, reaching the targets set by the Paris Agreement will require additional action, such as expanding renewable energy, decarbonizing the transport and industrial sectors, rapidly phasing out coal, and investing in carbon removal.

[1] See the report here: https://www.unep.org/resources/emissions-gap-report-2021

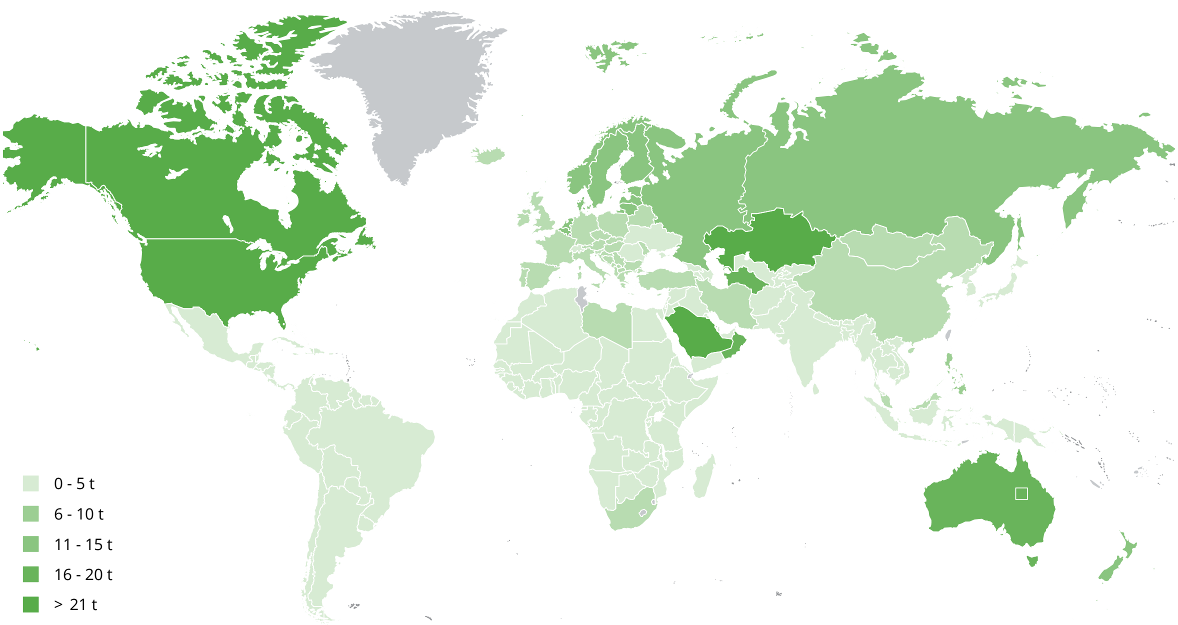
Exhibit-1.2: Global CO_2 emissions in an orderly 1.5°C transition



Source: McKinsey Energy Insights Global Energy Perspective 2021, December 2020; McKinsey 1.5ºC Pathway

Developed regions are big contributors to CO_2 emissions on a per capita basis, in particular, North America, Europe, Northeast Asia, and Australia. However, countries that are active in oil production, such as Saudi Arabia and Kazakhstan, are among the highest contributors in their regions and worldwide. Africa and Latin America contribute relatively little to CO_2 emissions; however, this is expected to change with increasing growth in GDP.

Exhibit-1.3: CO_2 emissions per capita in 2017, metric tons of CO_2



Source: Carbon Dioxide Information Analysis Center; Global Carbon Project; Gapminder; United Nations

POLICIES IN SELECT COUNTRIES & REGIONS

The European Union, United States, and China contribute more than 50 percent of global CO_2 emissions. They have put forth the following nationally determined contributions (NDCs) under the Paris Agreement:

THE EUROPEAN UNION (EU)

By 2050, the EU aims to be climate neutral. The target is expected to be reached through systems such as the EU Emissions Trading System, the world's first major carbon market. The European Union submitted its NDCs with the following targets:

EU NDC TARGETS

1. Cut GHG emissions by at least 55 percent from 1990 levels by 2030
2. Increase renewable energy share to at least 32 percent
3. Improve energy efficiency by at least 32.5 percent

THE UNITED STATES OF AMERICA (USA)

The Biden administration brought the United States back into the Paris Agreement. The country has set the following goals for fighting climate change:

USA NDC TARGETS

1. Reduce GHG emissions by at least 50 to 52 percent from 2005 levels by 2030.
2. Be climate neutral by 2050

CHINA

China became the world's largest emitter of carbon dioxide in 2006 and is now responsible for more than a quarter of the world's overall greenhouse gas emissions.

In 2020, China's President Xi Jinping said his country would aim for its emissions to reach their highest point before 2030 and for carbon neutrality before 2060.

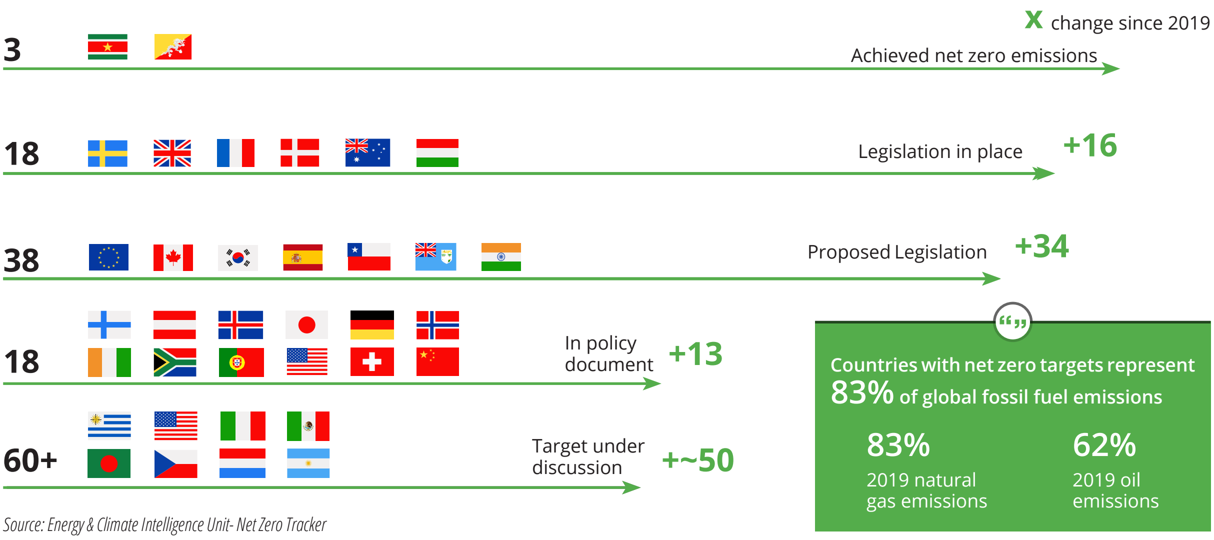
CHINA NDC TARGETS

1. Reduce GHG emission intensity by at least 65 percent from 2005 levels by 2030.
2. The share of non-fossil share in primary energy mix to be around 25 percent by 2030
3. Be climate neutral by 2060

CURRENT RESPONSE IS INSUFFICIENT TO LIMIT GLOBAL WARMING

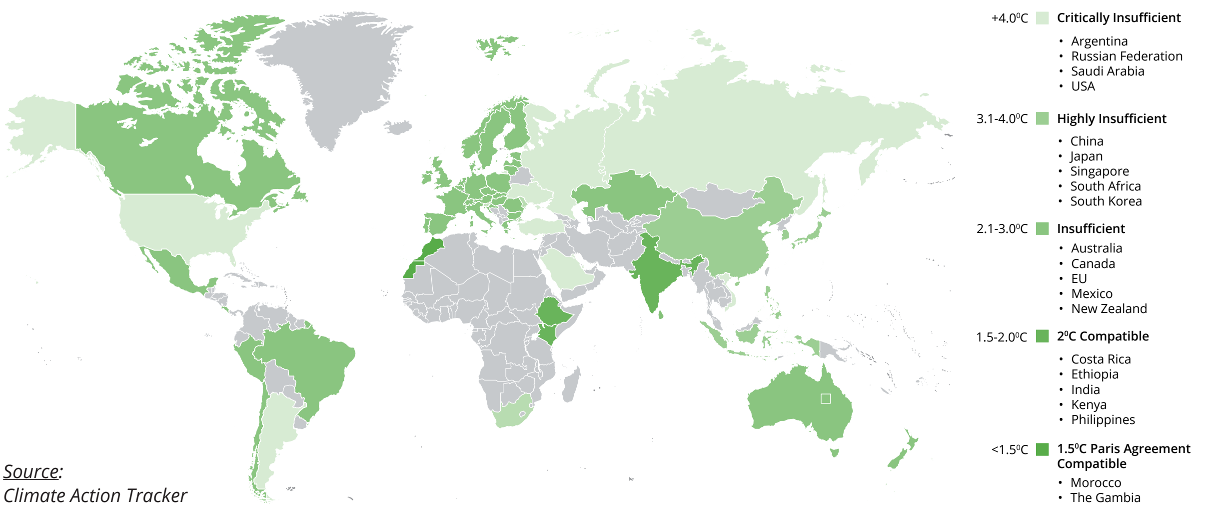
As of November 2022, 139 nations have committed to achieving net zero. Only three countries (Bhutan, Suriname and Panama) have already achieved net zero, 18 countries have all the necessary legislation in place, and another 38 have proposed suitable legislations. Currently, 18 countries are working on a policy document and more than 60 countries are working on arriving at a target. The countries that have established net-zero targets represent 83 percent of all fossil fuel emissions.[2] India has committed to be net zero by 2070, with current policies consistent with 2°C temperature rise However, the current policy pathway is expected to lead to warming of 2.7°C to 3.5°C by 2100. Government policies have very limited scope; carbon markets set up by governments only cover 20% of global emissions, and policies of two of the top CO_2 contributors, the European Union & United States, would lead to a temperature rise of more than 2°C and 4°C, respectively.

Exhibit-1.4: Countries that have committed to net zero by 2050



Source: Energy & Climate Intelligence Unit- Net Zero Tracker

Exhibit-1.5: Current policy warming scenarios



Source:
Climate Action Tracker

[2] Net Zero Tracker, Energy & Climate Intelligence Unit

MINIMAL LONG-TERM IMPACT OF THE COVID-19 PANDEMIC ON EMISSIONS

As economies recovered, emissions in 2021 rebounded by 4 percent after declining 5 percent in 2020. Global emissions in 2021 remained one percent below 2019 levels. Both coal and gas emissions were higher than 2019 levels, and oil emissions only partially rebounded in 2021, mainly due to the slow recovery in aviation.

In most countries, emissions in 2021 remained below historical trajectories, regardless of whether their emissions are structurally declining (i.e., past the emissions peak) or growing. Unlike other countries, China's emissions grew in 2020, driven by rapid recovery and growth in coal consumption during the second half of 2020. High GDP growth in 2021 accelerated the increase in emissions past China's historical trajectory.

Overall, the majority of the emissions reduction impact of the COVID-19 pandemic was temporary, as economies began to recover in 2021.

During pandemic, greenhouse gas emissions plummeted by a record amount. But, in the grand scheme of climate change, this historic reduction was but a blip with little impact on atmospheric carbon dioxide levels ...

... Austerity cannot lead to a net zero economy. Green transition needs a new mode of production and consumption. Post-crisis investments must accelerate economic transformation to ensure that we recover better together".

- UN.org

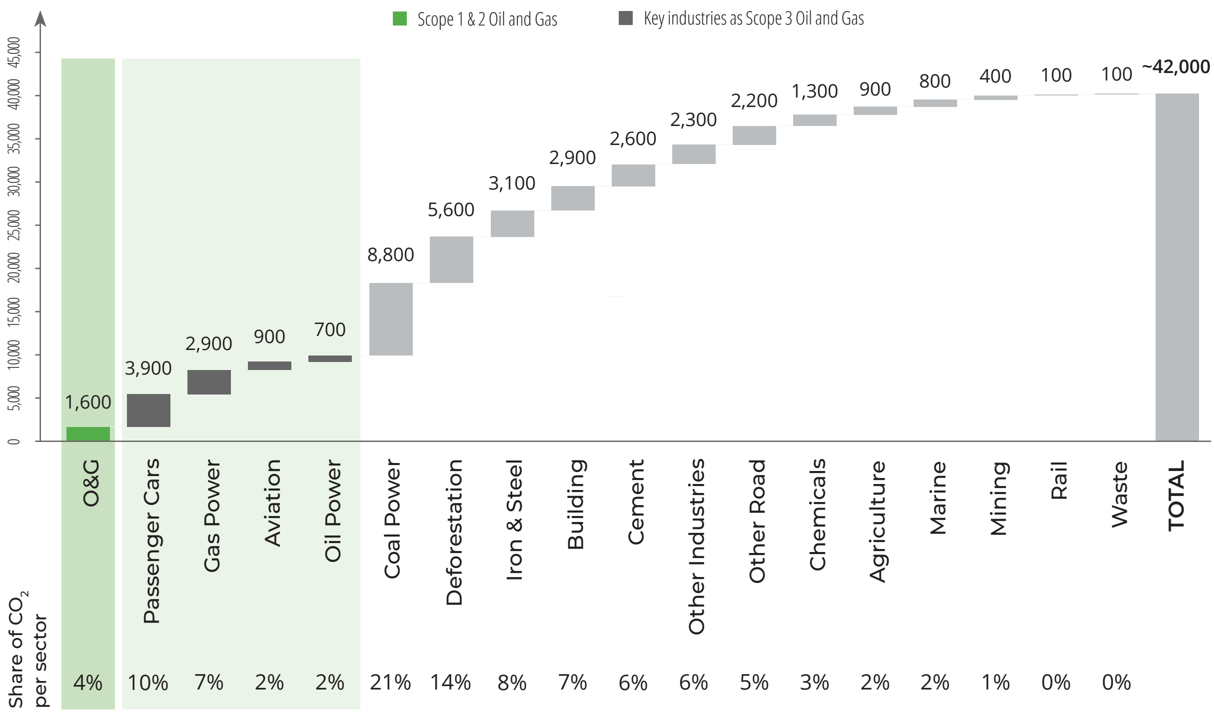
Photo Credit: Adobe Stock

ROLE OF THE PRIVATE SECTOR

Across the world, the onus for halving emissions by 2030 to move toward the 1.5°C target falls heavily on the power sector, industry, and mobility, which together contribute over 80 percent of the entire CO_2 emissions.

Energy use alone accounts for 83 percent of the CO_2 emitted worldwide. Power and industry are major consumers of energy and generate around 60 percent of all CO_2 emissions.

Exhibit-1.6: Scope 1 & 2 CO_2 emissions in 2020, Mt CO_2 per sector

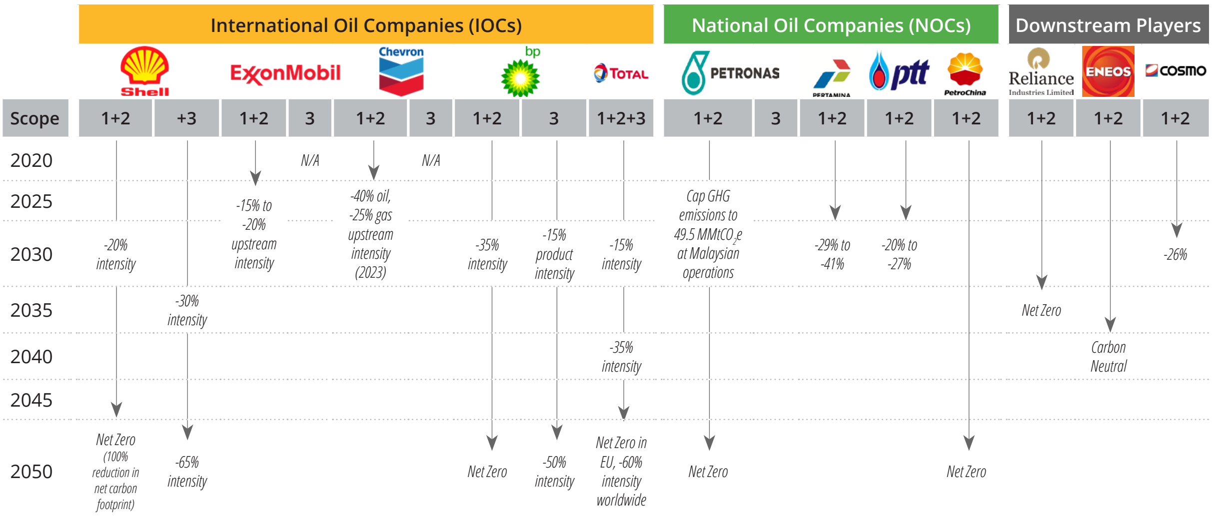


Source: Global Energy Perspective – Reference Case 2019; McKinsey 1.5°C Scenario Analysis

The decarbonization of oil and gas is an increasing priority, given the industry's scale and carbon intensity. In oil and gas, scope 1 and 2 emissions account for about 4 percent (approximately 1,600 million tonnes of CO_2 per year) of global CO_2 emissions, whereas scope 3 emissions for oil and gas are larger than scope 1 and 2 combined, at about 8,400 million tonnes of CO_2 per year (approximately 20 percent of the global total) if combustion of products is included. Within the industry globally, upstream operations contribute about 40 to 50 percent of emissions in oil and gas, while refining operations contribute 30 to 40 percent of emissions. The world is likely to continue using fossil fuels to secure energy for a long time. Therefore, the fossil fuels industry can be part of the solution and contribute towards lowering its carbon footprint and elongating legacy assets' usage life through better energy efficiency, focused control of its operations and improvements in its supply chain besides technological enhancements in core operations as the world treads on its journey towards net zero.

As countries have announced net zero commitments, so have many corporations. Already, nearly 3,000 corporations and financial institutions are working with the Science-based Targets Initiative (SBTi) to reduce their emissions in line with climate science. The Indian oil and gas companies, being aware of the task at hand, are gearing towards their net zero targets.

Exhibit-1.7: Decarbonisation targets set by various Oil & Gas Companies

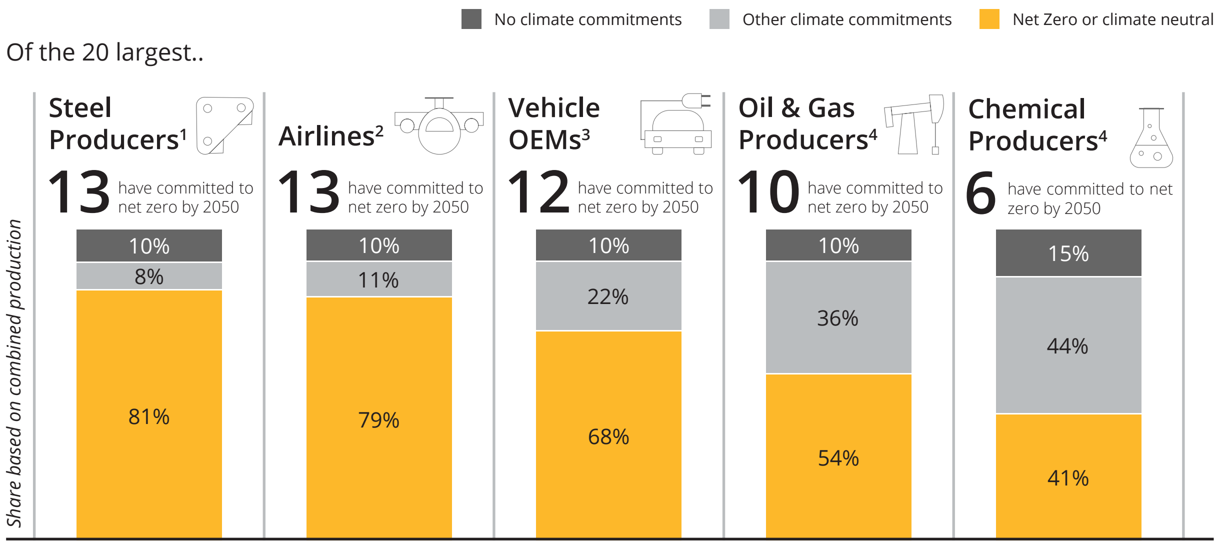


Source: Company Reports

Even in hard-to-abate sectors, some of the world's largest companies are setting ambitious decarbonization targets. Climate commitments made by majority of top 20 companies in the steel, aviation, vehicle original equipment manufacturers (OEM), oil and gas, and chemicals sectors address over 85 percent of their combined production.

In all these sectors, the top 20 largest companies represent at least 30 percent of their entire sector, with the top 20 vehicle OEMs representing 85 percent of the total sector production. Between six to 13 of the top 20 companies in each sector have taken their ambitions a level further and committed to net zero or climate neutrality.

Exbibit-1.8: Companies with net-zero targets in their respective sectors, out of the top 20



[1] 20 largest steel producers represent ~38% of global production;

[2] 20 largest airlines represent ~20% of global air traffic;

[3] 20 largest vehicle OEMs represent ~85% of global car sales;

[4] 20 largest oil & gas producers represent ~54% of global production;

[5] 20 largest chemical producers represent ~50% of global production

Source: Company reports; Science Based Targets

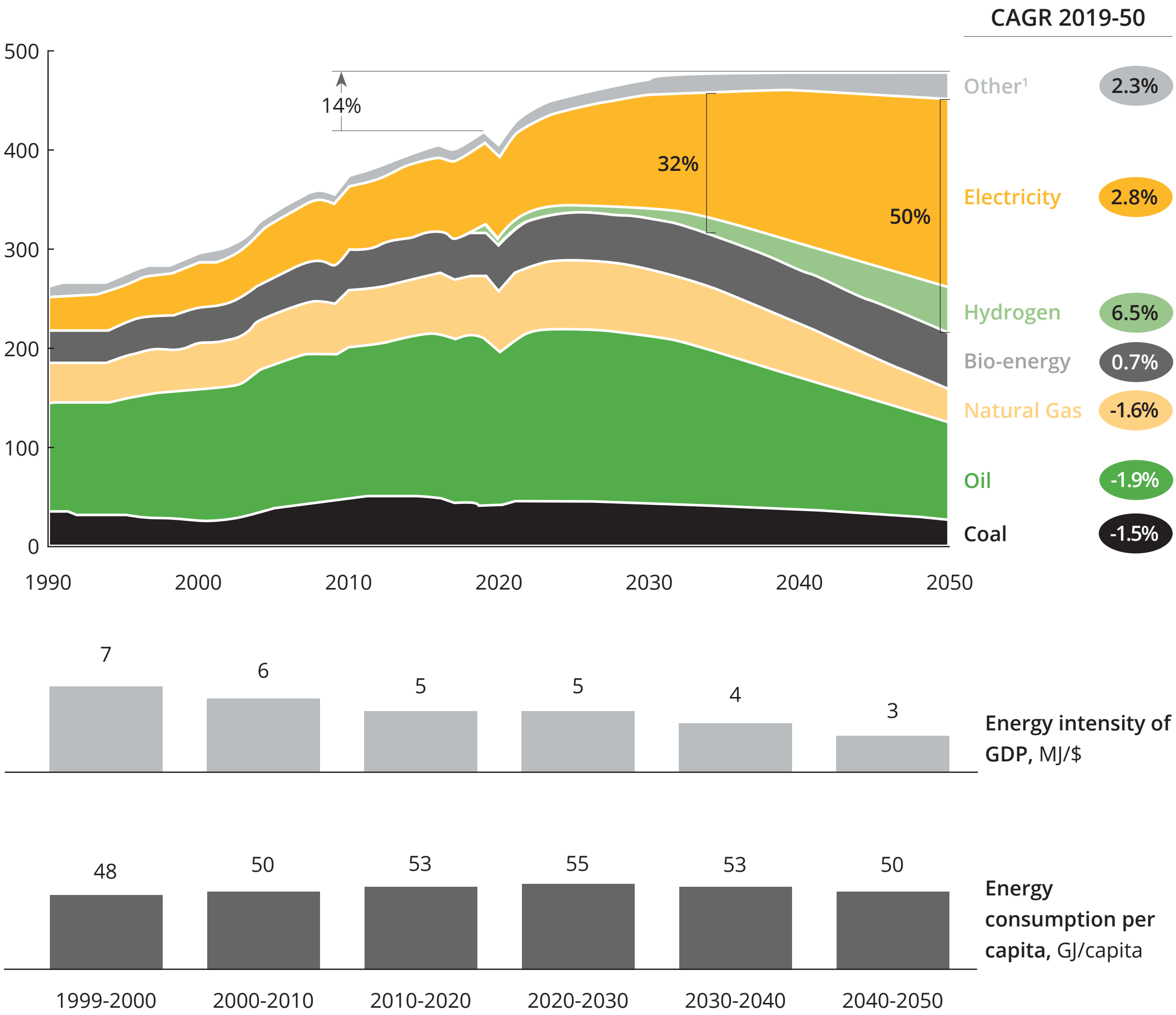
CHANGE IN GLOBAL ENERGY MIX

Despite the rapid growth of the global economy and population increase by two billion people, energy consumption is projected to grow by only 15 percent until 2050.

Continued reduction in the energy intensity of GDP is going to be a key driver, triggered by a rise in end-use efficiency of buildings, transport, and industry, as well as electrification, as a shift to electrical solutions tends to come with a large increase in efficiency in many segments, such as space heating and passenger cars.

The share of electricity in the final consumption mix is expected to grow from approximately 20 percent today to 40 percent by 2050. The corresponding doubling of electricity consumption, combined with the uptake of hydrogen, is expected to offset fossil fuel consumption (excluding primary demand for coal and gas for power generation), which is expected to be about 40 percent lower in 2050 compared to 2020.

Exhibit-1.9: Final energy consumption by fuel, Million Tera-joules



[1] Includes heat and synthetic fuels

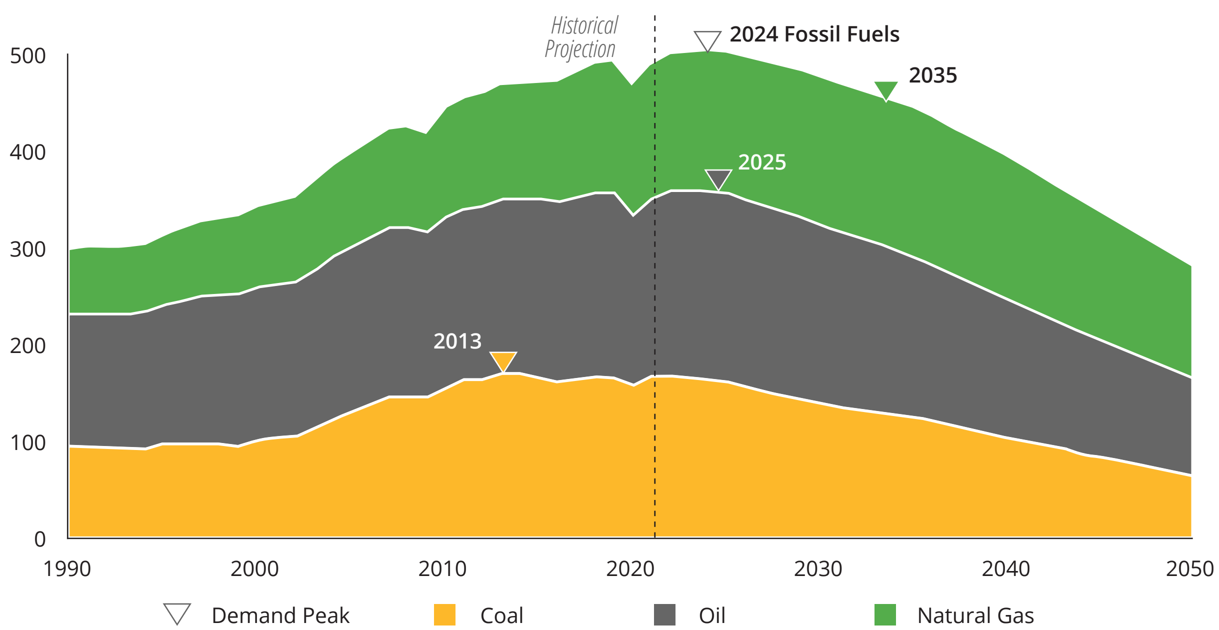
Source: McKinsey Global Energy Perspective 2022

PROJECTIONS FOR FOSSIL FUEL & RENEWABLES

Total global fossil fuel demand is projected to peak before 2030 and is expected to drop by 40 percent by 2050 when it will make up only 43 percent of global energy demand. Natural gas is projected to continue to increase its share of the global energy demand in the next 10 to 15 years, the only fossil fuel to do so, and demand is expected to peak in the late 2030s. Oil demand growth is expected to slow substantially, with a projected peak in the early 2020s, followed by a 51 percent decline in demand by 2050, mainly driven by declining car-parc growth, enhanced engine efficiency in road transport, and electrification. Coal demand is projected to decrease by almost 65 percent between 2019 and 2050, driven mainly by phaseout of coal plants in the power sector across regions. While fossil fuels are expected to see a significant reduction in their role in the energy mix, the trends are expected to be divergent in different parts of the world. In general, while fossil fuels will cede their supremacy to renewables in the developed world, their usage in absolute terms is likely to continue increasing. So there will be a time when fossil fuel usage will show divergent trends in different parts of the world, but even within this set of countries, they will cede part role to renewables which will see their share rise over the years. It is also expected that gas being an ideal bridge source of energy, could witness its share go up within ever reducing contribution by fossil fuels in some particular country / set of countries.

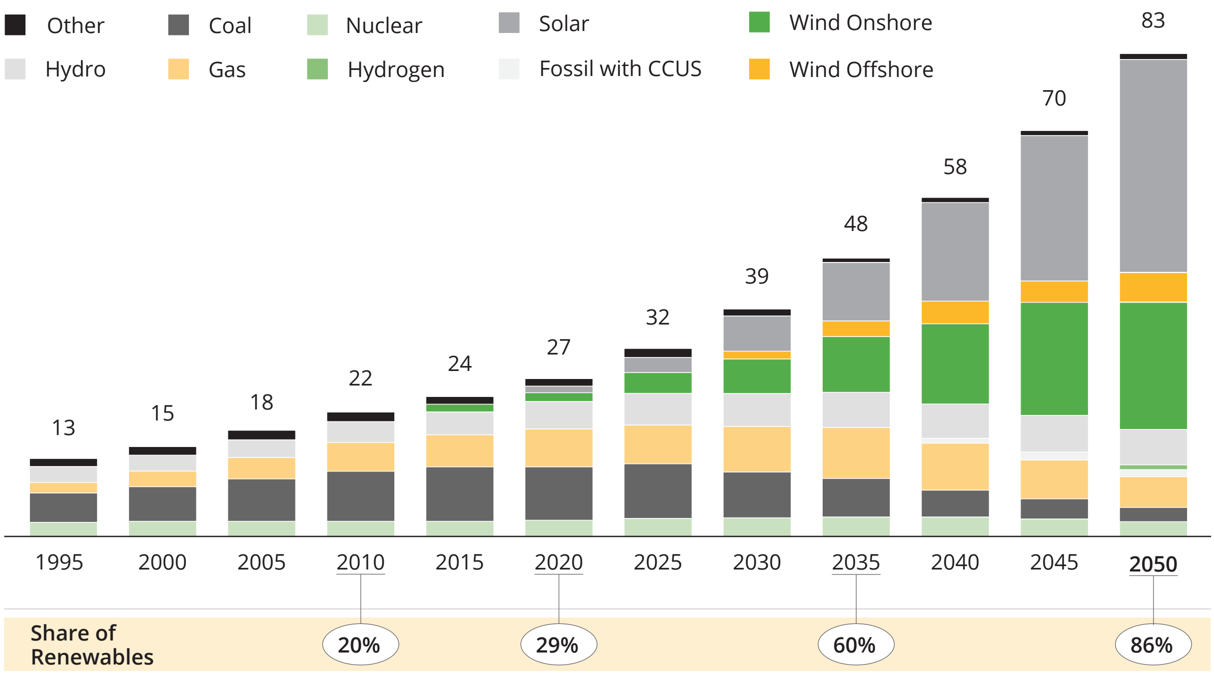
Renewables are projected to dominate the power generation mix, reaching up to 80 to 90 percent in 2050. Due to declining costs, most of the growth is expected to come from solar and onshore wind, which are predicted to make up 43 percent and 26 percent of generation, respectively, in 2050. Offshore wind is projected to make up less than 7 percent of global generation due to permitting constraints and policy hurdles, with the potential to grow further if constraints arise for onshore wind, such as land use. Thermal generation is still expected to play an important role as a flexibility provider, with gas providing a substantial share of baseload generation up to 2040 in regions with favorable fuel costs. Nuclear generation is still expected to require economic support from policies, which is not yet present in many regions as public acceptance continues to prove challenging.

Exhibit-1.10: Global fossil fuel demand, Million Tera-joules



Source: McKinsey Global Energy Perspective 2022

Exhibit-1.11: Global power generation, Thousand Tera-Watt Hours



Source: McKinsey Global Energy Perspective 2022

LONG-TERM TRENDS DRIVING TRANSITION

In the past five years, technological improvements, economies of scale, and supply-chain optimization have lowered the cost of solar photovoltaics (in dollars per kilowatt) by 50 percent and the cost of wind by 29 percent, resulting in their fast adoption. This has resulted in energy from 61 percent of new renewable capacity installations being cheaper than from the plants using fossil fuel alternatives.

Continued research and expanding production capacity are driving down battery costs for electric vehicles and grid balancing, which declined by 42 percent from 2017 to 2021.

Battery technology is in the transformative phase on almost all relevant KPIs, for example, energy density, thermal stability, charging life cycle and cost per kWhr. These factors have lowered the overall upfront cost of acquisition as the total cost of ownership has gone down, and performance has improved.

For an electric 2W vs. a petrol 2W, operating costs considering fuel, maintenance, insurance, and financing is ~30% and the same are ~50-60% for an electric car vs. a gasoline car, leading to a TCO break-even for most vehicle types over the next 10-15 years, led by 2Ws, followed by cars and then CVs.

Additionally, the missing piece for renewable energy is the long duration energy storage technologies which will impact prices with the declining costs of batteries.

Emissions trading system schemes are increasing the price of emissions in Europe, with average CO_2 prices in the EU increasing ninefold over the last five years.

Overall, these technology trends are expected to keep driving the adoption of renewable sources of energy and accelerate the transition away from crude oil-based sources.

CONCLUSION

Based on the current policy pathway defined by countries across the world, it is expected that the planet will be 2.7°C to 3.5°C warmer than the pre-industrial temperature levels by the end of this century. The EU, United States, and China, which contribute to more than 50 percent of global CO_2 emissions, have set their aspirations to become climate neutral by 2050 to 2060. However, these policies would lead to a temperature increase of more than 2°C and 4°C, respectively, which is not in line with the 1.5°C pathway.

To successfully meet the 1.5°C target for limiting global warming, it is important to reduce GHG emissions in the next eight years by around 50 percent, in addition to other actions, such as expanding renewable energy, decarbonizing the transport and industrial sectors, rapidly phasing out coal, and investing in carbon removal.

Nearly 1,200 companies have established science-based targets, and twice as many have taken decarbonization action. Climate commitments made by the majority of the top 20 companies in the steel, aviation, vehicle OEM, oil and gas, and chemicals sectors address over 85 percent of their combined production, thus accelerating the energy transition.

The role of electricity in the final consumption mix is expected to grow from approximately 20 percent today to 40 percent by 2050. As most projections suggest, total fossil fuel demand is projected to peak before 2030 and is expected to drop by 40 percent by 2050 when it will make up only 43 percent of global energy demand. Renewables are, thus, projected to dominate the power generation mix, reaching up to 80 to 90 percent in 2050. In view of differing ground conditions, the trends and the role to be played by different sources could see divergent trends.

In India, MS and HSD demand are expected to peak in 2040 and are projected to decline post that due to the electrification of vehicles. LPG demand is expected to decline after 2030 due to the electrification of cooking and reduce to zero with 100% electrification by 2070. The demand for Aviation Fuel will continue to grow at 3.5% CAGR but will be gradually substituted by SAF (50% blending by 2070) due to CORSIA mandates. Naphtha demand is expected to rise at 4.5% CAGR (2030-50) and 2.3% CAGR (2050-70) because of increasing demand for petrochemicals. However, effective demand will be lower because of the increase in recycling activities.

The rate of transition in fossil fuel consumption is primarily dependent on the shift in the auto sector to EVs. With an aggressive transition to EVs due to policy mandates, there will be accelerated repurposing / closure of refineries for renewable energy / biofuel production and reduction of overall carbon footprint.

Due to declining costs, most of the growth in renewables is expected to come from solar and onshore wind. It is expected that this trend of lowering costs will continue, resulting in faster adoption of renewables and an accelerated transition from conventional fossil fuels.

The world hopes and seems to be committed to an orderly, painless and systematic transition. However, it is quite likely that the world will witness turbulence of varying magnitude as it traverses its net zero journey. A world where all stakeholders contribute and collaborate in achieving this common objective could eliminate the pain. However, any transition intending to move away from 80% of current energy sources and their replacement by renewables will face turbulence. At times the transition is going to be messy. A case in point is the recent problems being faced the world over due to the trinity of rising inflation, falling energy supplies and challenges to the global political order and heightened tensions. Definition of what is sustainable and what is not will also keep getting upgraded over time as the world becomes aware of the effects of the new energy order. Sometimes the ground realities (like increased usage of coal in many parts of the world during the past few months and the recent discussions around gas and nuclear being green) will dictate the choices, but hopefully, the world will figure out a way to make it happen and help in leading towards a 1.5-degree world.

Photo Credit: Adobe Stock

Chapter 2

THE INDIAN ENERGY TRANSITION

In this section

THE STORY IN INDIA

Events over the last two years have brought the issue of energy security to the forefront all over the World. The monopoly of some countries over the production and supply of energy, particularly oil and gas, and the dependence of certain nations on imports to meet even the basic energy requirements together have brought to the fore global vulnerability, where the sustained supply of energy was so far taken for granted. The world operated on the assumption of a free, interdependent and transparent energy market where the demand and supply get balanced through the interplay of market forces. Disrupted supply chain and record high energy prices in the wake of recent geopolitical events all raise the need to move away from these assumptions and portend a painful and messy transition. Thus India would need to tread a transition path based on two pillars, viz. increasing its share of electricity in final energy consumption and harnessing the full potential of domestic renewable resources, which will result in reduced dependence on imports and provide the much-needed push to the rural / agri-based economy. During the transition, it needs to be ensured that the grid power supply reliability is consistently improved. Currently, only about 18% of India's energy needs are met through power flowing from the grid. This has to increase fast to >40% by 2035. India must also look for technologies to use coal without causing much environmental damage in the medium term, for which R&D efforts need to be continued.

An increased share of renewables will also throw up challenges for balancing the grid due to ever-increasing electricity consumption and intermittency of electron supply through renewables. The grid's transition from largely coal-based fuel generation to renewable sources has to happen fast. India has set a target of 500 GWs of non-fossil fuel installed capacity by 2030. The government has already developed a trajectory for renewable purchase obligations to achieve this. This involves an increasing share of Solar and Wind as the primary sources, with Solar playing the lead. India also needs to explore the possibility of increasing the share of Hydro. However, to balance the grid, a healthy ratio must be maintained with a good combination of Wind,

Solar and Hydro. The changed energy mix would also require investments in energy storage. In view of the same being costly at this stage, the National Load Dispatch Centre has to play a more active role. A thorough study of the load curve in various parts of the country and regional variation in energy consumption patterns needs to be carefully carried out to ensure that all these major seasonal variations are taken care of at the national level. Therefore, creating a national supply pool controlled by National Load Dispatch Centre could be a good idea. Older coal-based thermal power plants may also not be retired but could be used for grid balancing.

Industry, a large energy consumer, is shifting slowly to electricity or natural gas. However, some hard-to-abate sectors like Steel and Cement still use a large quantity of coal due to their peculiar requirement. These industries should shift to electricity as feasible. Natural gas can be the transition fuel for the next 15-20 years.

Buildings are another category consuming a considerable quantity of energy. The requirement for energy for buildings will continue to grow as more and more buildings becomes air-conditioned. This could be a large growth area as far as energy requirement in India is concerned. Energy-efficient building designs with provision for rooftop solar for new buildings have to be made mandatory. There is a requirement for an updated national-level building rating system that should include renewable energy usage. This will generate a requirement for many rating agencies and rating domain professionals to cover the entire country. We already have an ECBC mechanism administered by the Bureau of Energy Efficiency. This has to include renewable energy and setup mechanism with the involvement of State Governments to cover the entire country. As the grid becomes progressively green, the energy consumed in the buildings which is primarily electricity through the grid would also become cleaner overtime.

India is among the few countries on track to achieve its 2030 climate commitments as part of the Paris Agreement. Over 35 percent of its power generation capacity comes from renewables (approaching its promise of 40 percent by 2030). India has achieved a 21 percent reduction in

Photo Credit: Adobe Stock

emissions intensity from its 2005 level (against a commitment of 33 to 35 percent). It has a current run rate of 1.9 to 2.0 GtCO2e in additional carbon sink by 2030 (against a commitment of 2.5 to 3.0 GtCO2e). The primary drivers of achieving this progress have been its ambitious solar and wind targets, the renewables status of large hydro plants, lower specific energy consumption targets, and a strategy for the 3.0 GtCO2e sink approved by the Indian government.

Exhibit-2.1: India's 2030 commitment, progress, and drivers

India's commitment in Paris Agreement for 2030	India's progress till 2030
40% RE in power generation capacity mix by 2030	☑ **36%** RE mix (including large hydro) achieved
33-35% Lower emission intensity of GDP in 2030 from 2005 levels	☑ **21%** Reduction in emission intensity achieved (tCO_2e per million $ GDP PPP) - ~2% reduction per year
2.5 - 3.0 $GtCO_2e$ additional carbon sink by 2030	☑ **1.9 - 2.0** Current rate of $GtCO_2e$ additional carbon sink by 2030

Drivers to achieve India's 2030 goals

Ambitious solar & wind RE targets
450 GW RE (i.e. 60% of capacity by 2030)

Renewables status for large hydro
50 GW of hydropower re-classified as RE

Lower specific energy consumption targets under PAT scheme
Cumulative 27 Mtoe saved through higher energy efficiency

Strategy for 3 GtCO2e sink approved by Indian Government
Focus on enhanced soil quality to store more carbon

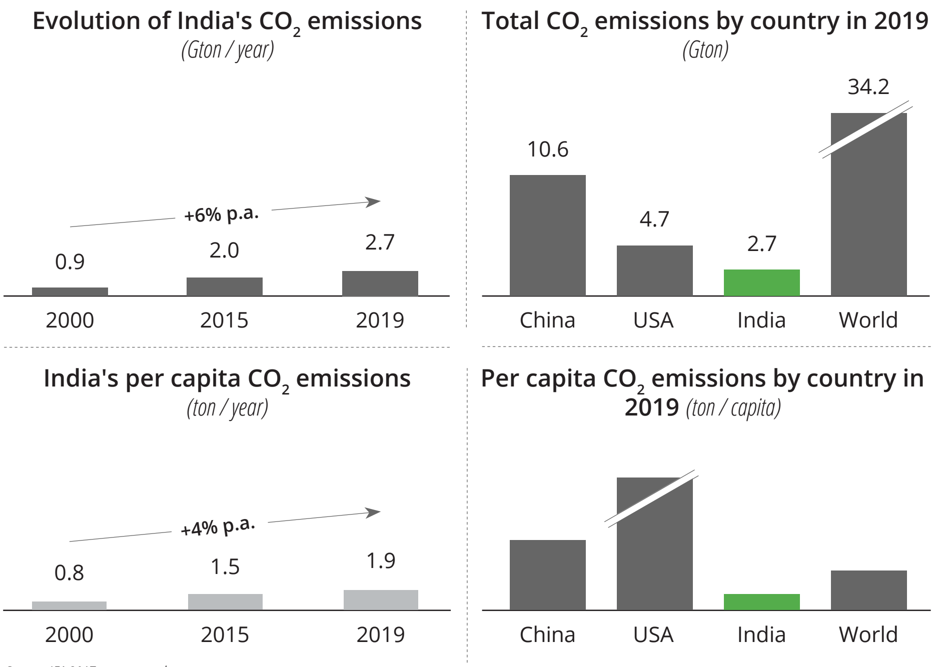
India is set to over-deliver on two of its three NDC pledges by 2030

Source: Mercom India; Climate Action Tracker; press search

More needs to be done, however, as India ranks among the third highest CO_2 emitters in the world. It has committed to attaining net zero by 2070, which lags behind the COP26 goal of getting to net zero by 2050.

There are multiple economic benefits to moving towards net zero. Our analysis indicates that a portfolio of five low-carbon economic activities can bring economic benefits to the country. Such a portfolio could involve developing a set of industries comprising component manufacturing for battery electric vehicles, offshore wind, solar panel manufacturing, development of storage solutions, industrial-scale production of electric heat pumps, electrified agriculture equipment manufacturing, & R&D and deployment of (bioenergy) carbon capture, utilization and storage technology.

Exhibit-2.2: India's current emissions



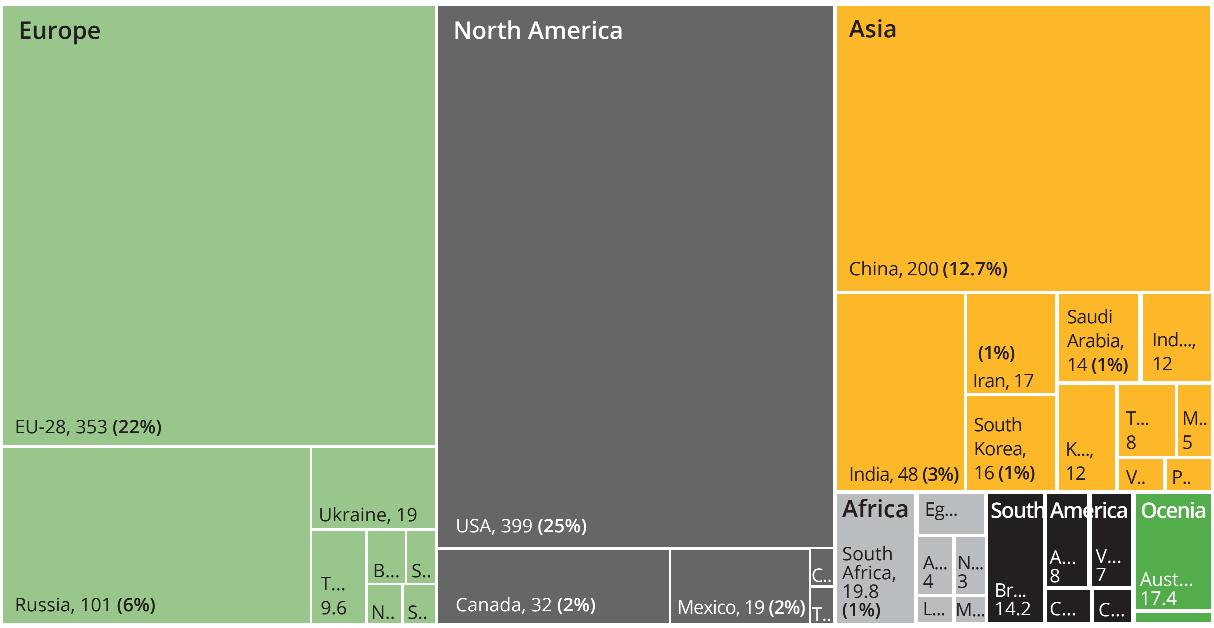
India has the 3rd highest total CO_2 emissions globally

Emissions are expected to grow by **5x** to **~13.6** Gton per year if emissions continue to grow at historical rate of **5%.**

Source: IEA 2017; press search

Exhibit-2.3: Cumulative CO_2 Emissions (in billion ton), for countries, 1751 to 2017

Cumulative carbon dioxide (CO_2) emissions represent the total sum of CO_2 emissions produced from fossil fuels and cement since 1751 and are measured in tonnes. These CO_2 emissions include contribution from fossil fuels and cement production only and does not include the impact of changes in land use. As can be seen in the exhibit, India's contribution to cumulative CO_2 emissions is barely 3% of the world's total emissions.



** Percentage indicates share of the country in global cumulative CO_2 emissions*

Source: Our World in Data

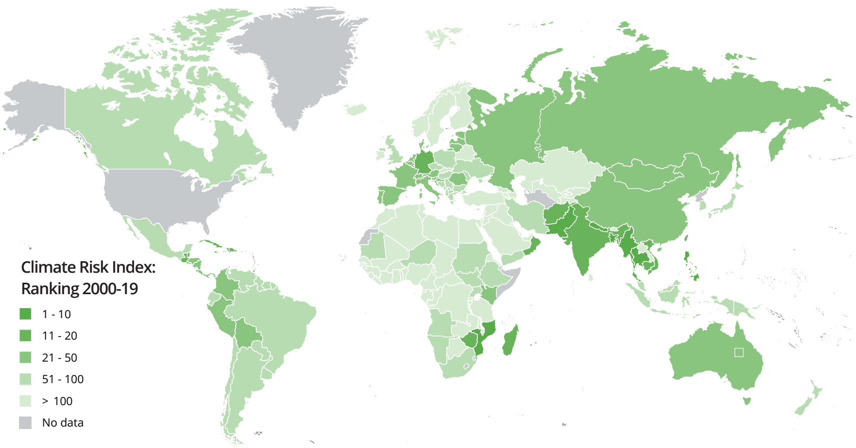
[1] Matt McGrath, "COP26: India PM Narendra Modi pledges net zero by 2070," BBC, November 2, 2021.

THE RISKS OF CLIMATE CHANGE

Over the last four decades, droughts and floods have become increasingly frequent across India. In just the last 15 years, the annual average number of drought-affected districts in India has increased 13-fold, affecting 140 million people annually. At the same time, flood events have risen fourfold, with 98 million Indians affected every year. The effects of climate change are already being felt around the globe, and India is one of the countries at the highest risk. This risk is likely to be aggravated if timely measures are not taken.

Exhibit-2.4: Global Climate Risk Index, 2000–19

Global Climate Risk assessed on the basis of loss to economy and life due to extreme climate events



India ranked ***7th in the world's most affected countries*** by climate change in the year 2019

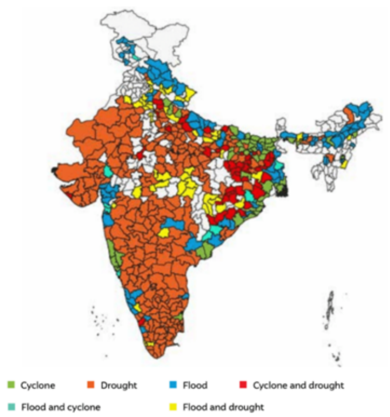
In 2019, overall ***11.8 Mn people were affected*** by intense rainfall and floods with ***estimated damage of US $10 bn***.

India faced ***8 tropical cyclones*** in 2019 with ***6 being categorized 'very severe'.***

Source: David Eckstein, Vera Künzel, and Laura Schäfer, "Global Climate Risk Index 2021: Who suffers most from extreme weather events? Weather-related loss events in 2019 and 2000 to 2019," Germanwatch, January 2021

India ranks seventh on the list of countries expected to be the most affected by global warming. It faced eight tropical cyclones in 2019, with six classified as "very severe." The total damage was estimated at $10 billion, with intense rainfall and floods affecting around 11.8 million people.

Exhibit-2.5: Climate event hotspots in India



>75% of Indian districts (home to 638 Mn people) are extreme climate event hotspots

Since 2005, **55+ districts** witnessed extreme flood events year-on-year, **exposing 97.51 million people** annually

After 2005, **24 districts** witnessed extreme cyclone events yearly, **exposing 42.50 million people**

258 districts hit by cyclone in the last decade

In the last 15 years, 70 districts recorded extreme drought events year-on-year, **exposing 140.06 million people annually** - yearly average of **drought affected districts increased 13 times**

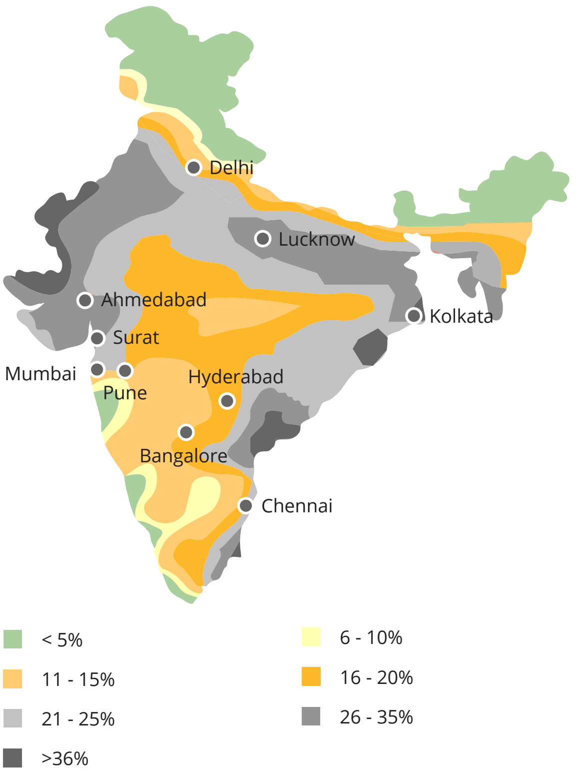
Source: Abinash Mohanty, Preparing India for extreme climate events: Mapping hotspots and response mechanisms. New Delhi: Council on Energy, Environment and Water, December 2020.

More than 75 percent of India's districts—home to 638 million people, or 1.4 times the population of the European Union (EU) are categorized as hotspots for extreme climate events. In the last 15 years, 79 districts recorded extreme drought events, exposing over 140 million people annually. Since 2005, more than 55 districts have witnessed extreme flooding events year after year, exposing almost 98 million people annually.

All these weather events establish the fact that the risk for India is real and imminent. The nation needs to act quickly to not only meet its commitments but to exceed them and set an example for the global community in terms of climate change management and energy transition. The need of the hour may be to identify areas for action that hold the potential for maximum impact in the shortest possible time. The states of Rajasthan, Punjab, Haryana, and Uttar Pradesh, which account for 27 percent of the Indian population, should be prioritized for immediate interventions, as they face the highest risk of global warming in India . This would occur as northern parts of India face a significant probability of lethal heat waves. As per the source, this would lead to lost working hours because heat and humidity are likely to increase significantly across India due to a rise in temperatures by 3 to 5°C by 2050. These changes in conditions may have a hugely detrimental effect on the GDP as the risk of heat and humidity increases with the rise of global warming. Additionally, these would lead to shortages in water supply, aggravating the problem further.

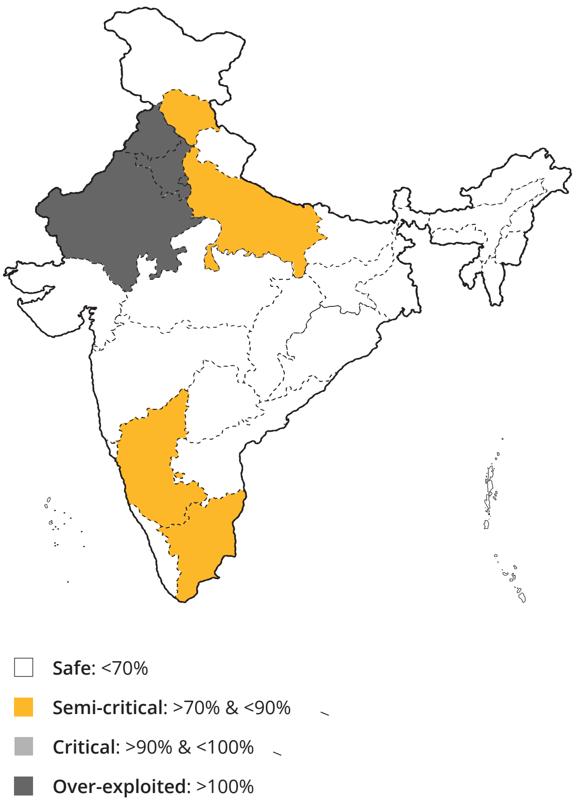
Exhibit-2.6: Some aspects of Climate Risk in India

Climate Risk: Heat & Humidity Trend in 2020



[1] *Annual share of effective outdoor working hours affected by extreme heat and humidity in climate exposed regions, %*

Ground water stress, 2017[2]



[2] *Annual ground water withdrawal / Annual groundwater recharge (%)*

[2] *Source: Woods Hole Research Center, McKinsey Global Institute analysis*

INDIA'S CURRENT STATE

Industrial and power sectors account for most of India's emissions of 2.7 $GtCO_2e$. Around one-third of emissions come from steel and cement sectors, followed by one-third from the power sector, and the rest from transportation and other sectors.

If we look specifically at greenhouse gas (GHG) emissions, power (almost entirely due to coal) and iron and steel manufacturing contribute around 75 percent.

Exhibit-2.7: Emissions per sector in India, by source and consumption

Sector	2019 CO_2e Emissions (By source, Bt CO_2)	2019 CO_2e emissions (By consumption, Bt CO_2)	CAGR (Past 20 years)
Power	1.2	0.3	4.6%
Iron and Steel	0.3	0.4	9.2%
Cement	0.2	0.3	5.6%
Road	0.3	0.3	6.6%
Buildings	0.1	0.4	6.1%
Agri and Waste	0.6	0.8	1.6%
Others	0.3	0.6	4.0%
Carbon Sink	-0.3	-0.3	4.0%
TOTAL	2.7	2.7	

Source: GEP India Baseline 2016, projected to 2019

Decarbonizing the power, industrial, and transportation sectors is thus crucial for emissions abatement in India, as they constitute a significant portion of emissions. Shifting to renewable power generation, electrification of heating in industries, clean fuels (such as hydrogen), better energy efficiency, and circularity in plastics can contribute to significant emissions reductions.

Net zero by 2070 asks for a focused roadmap and timely intervention by the Government, apart from large capex requirements in GHG emitting sectors like power, industry, and transport. The roadmap will benefit India with new technologies, hence there would be new business opportunities in the area of energy efficiency, carbon reduction, green fuels etc.

The government has notified the Production-Linked Incentive (PLI) scheme with a financial outlay of Rs. 45 billion to promote the domestic manufacturing of high efficiency solar modules with full backward integration. The government is also augmenting the outlay to Rs. 240 billion .

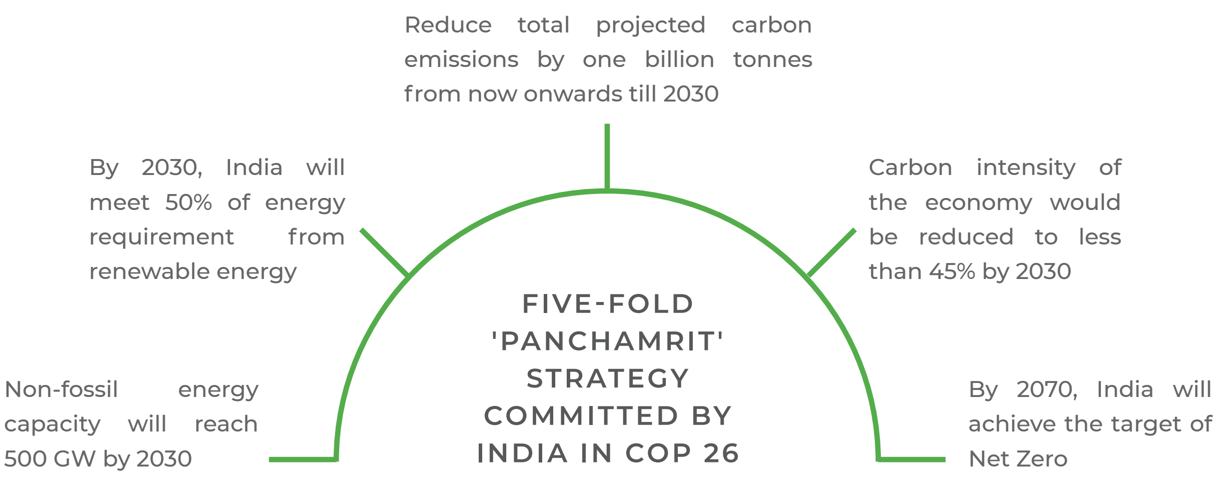
"Go Electric" Campaign - A Pan India initiative targeted to spread awareness of the benefits of e-mobility and EV charging infrastructure and boost the confidence of EV manufacturers. The Government's PLI Scheme has a planned outlay of Rs 1,400 – 1,600 billion, which includes Rs 180-190 billion for batteries.

The government initiated Expressions of Interest (EOI) for "Procurement of Bio-diesel produced from Used Cooking Oil" in August 2019. It also notified the National Policy on Biofuels to promote the use of ethanol, biodiesel, hydrogen etc. In the transportation sector, emissions are likely to peak by 2025, with cars, trucks, light commercial vehicles, and buses emitting high levels of CO_2. Trucks could change the game if their emissions levels drop from the current 26 percent share of all mobility emissions. Decarbonization in the transportation sector could happen through changes across three dimensions: economics and market variables, changes to the regulatory environment and vehicle parc, and the technology timeline. By far, the biggest GHG producer in the mobility system is road transportation. Tailpipe emissions from cars, trucks and other vehicles make up ~75 percent of all emissions from transportation activities compared with ~13 percent from aviation, ~11 percent from maritime transport, and one percent from rail transport.

A major lever for decarbonizing the transportation sector could be a higher focus and utilization of Indian Railways (IR) to transition to an electrified rail network. This would also need IR to move away from a diesel-powered rail network. As of 2015, IR used predominantly coal-based power and diesel fuel. It has electrified 38% of its track (in route kms), which carries approximately 63% of freight and 50% of passenger traffic . IR has aggressive plans for electrification of its fleet. An electrified rail network can more easily transition to clean energy alternatives such as solar and wind power, whereas there is limited availability of clean fuel alternatives. Selective initiatives that take road mobility towards electrified rail mobility, e.g., DFCs, RRTs, etc., would need to be fast-tracked.

It is expected that IR will be able to complete electrification across all segments, whether short, medium or long haul, soon. This will help address even the remaining emissions from rail movement. Given the significant advantages of IR as a means of mobility for passengers and goods, there is a need to promote railways as a means of mobility across both the goods as well as passenger segments. Besides having positive implications from an emissions perspective, this could become a safer and cost effective mode of transportation and help create greater economic, social and cultural integration within the country.

Exhibit-2.8: India's Climate Commitments



These ‘Panchamrit’ will be an unprecedented contribution of India to climate action.

A latest happening has been India dropping the target on reduction of cumulative emissions by 1 billion tonnes by 2030. Also, the two targets on % and capacity of renewables have been merged into a single clear target for renewable power. These targets were approved by the cabinet in August 2022. The Net Zero Emissions Bill, 2022 was introduced in Rajya Sabha on December 09, 2022. The bill to provide a framework for achieving net zero emissions by the year 2070 as per India's nationally determined contributions under the United Nations Framework Convention on Climate Change.

[3] Source: https://www.icraresearch.in/Research/ViewResearchReport/4117

[4] https://www.climatepolicyinitiative.org/wp-content/uploads/2016/07/Decarbonization-of-Indian-Railways_full-report.pdf

THE CHANGES NEEDED TO SUPPORT DECARBONIZATION

To effectively support the decarbonization efforts, three social & economic changes must happen in India:

1. Catalyzing effective capital reallocation and new financing structures
2. Managing demand shifts and near-term unit cost increases
3. Establishing compensating mechanisms to address socio-economic impact

Exhibit-2.9: Societal and economic changes for supporting decarbonization

Capital Reallocation

Scaling up climate finance:

» $3.5 trillion increase in spending on low-emissions assets vs today

Develop new financial instruments:

» SPVs for setting up low emission assets

» Long-term purchase agreements

Pricing externalities to rebalance incentives:

» Policies to encourage capital spending in emission reduction projects

» Funding the repurposing or decommissioning of reduntant assets

Demand shift Management

Building transparency around climate risks and opportunities:

» Climate stress test for factoring risks in investment

Identifying measures to manage cost increases:

» Distribute the impact of cost increase across value chain

Incentives for making low emission tech cost competitive:

» Lift demand for loss emission tech to achieve economies of scale

Compensation Mechanism

Supporting economic development and diversification:

» Expediting the timeline for $100 Bn climate support fund

Reskilling and redeployment of workers:

» Retaining workers for right skills needed in a low-carbon economy

Instituting support for displaced workers:

» Options for aiding displaced workers e.g., income-support measures and subsidies

Source: McKinsey Report, May 2022

CATALYZING EFFECTIVE CAPITAL REALLOCATION AND NEW FINANCING STRUCTURES

As discussed, the net-zero transition will require both an increase in capital spending on low-emissions assets, as well as the reallocation of capital from high-emissions assets to low-emissions assets. Several measures could help accelerate capital allocation, as follows:

Scaling-up climate financing

Many public and private financial institutions have committed to net zero emissions and funding activities integral to the net zero transition. Significantly more financing will be needed for India to achieve its decarbonization targets. Requisite funding could come from both traditional financial instruments and more specialized instruments, such as green bonds, as discussed in the next point. Partnerships between financial institutions and real-economy stakeholders can help marshal financing as well. There is a need to step up efforts to secure the funding of Indian transition, building on the positive move of creation of a "Loss & Damage" fund during COP-27.

Developing new financial instruments & products

New financial products and structures can help companies wind down legacy assets and scale up new low emissions assets. Among the possible solutions are special purpose vehicles (SPVs) that enable companies to ring fence legacy assets with high emissions and retire them in line with a net zero pathway. They could also develop financing structures such as long term purchase agreements from low emissions plants, which have lower total lifecycle costs, to replace coal-generation assets. New financial instruments could also become an option for promoting negative emissions or nature-based solutions.

Nurturing & scaling the voluntary carbon markets

Developing and scaling voluntary carbon markets in the near term and compliance markets in the longer term could play a role in financing the transition. Carbon credits could become an important vehicle for financing the net zero transition to complement company efforts to decarbonize their operations. They could, for example, help channel capital to forest rich developing countries where there is potential to prevent deforestation or plant new forests. Voluntary carbon markets would include markets for both avoidance credits (for example, to prevent forests from being cut down) and removal credits (for example, from afforestation or direct air capture). For this to happen at scale, the world will need to build voluntary carbon markets that are large, transparent, verifiable, and environmentally robust. Given its track record, India is well positioned to create conditions for such a movement through its demonstrated leadership credentials on many global issues. The Taskforce on Scaling Voluntary Carbon Markets has estimated that demand for carbon credits could increase by a factor of 15 or more by 2030 and by a factor of up to 100 by 2050, and the market for carbon credits could be worth upward of $50 billion in 2030. Assumption of G20 presidency by India creates an opportunity to take lead towards creating a new narrative for balancing the growth and climate concern with equity at the core of the agreed framework.

Pricing externalities to re-balance incentives

The government might consider how various policies where organizations pay for their emissions could encourage capital spending in emissions reduction projects. Carbon pricing could also generate revenue that governments might use to support the transition.

Backstopping low-carbon investment & scaling-up public financing

Public authorities or private companies could consider assuming some of the risks of investing in low carbon projects through public guarantees or other risk hedges so that investors will be more likely to finance them. This can help support capital flows to sectors and geographies with large financing gaps. Public financing on a national and global scale could be used to fund key infrastructure investment that has a positive impact but may be more difficult to finance through markets (for example, electric vehicle charging stations, hydrogen fuelling stations, and carbon sequestration). India may have to consider setting up of a new Developmental Financial Institution (DFI) to support transition.

Purpose driven creation, or decommissioning of redundant assets

India is well positioned to chart its transition journey such that asset creation and investments are channelized as a policy, keeping in mind the carbon footprint and medium to long term imperatives of transition. This will not only help expedite the achievement of goals ahead of time, it will also reduce 'regretted investments' needing to be retired ahead of technical life expiry, decommissioning & retirements. Further, various options are available to organizations that wish to hasten the retirement of redundant assets. One proposed mechanism to accelerate the decommissioning of coal fired power plants would involve purchasing plants so that they can be retired ahead of schedule and then having the owners invest the proceeds in low emissions energy projects. Multilateral or government funds could be used to manage the ramping down of emitting assets and minimize the value at risk from stranded assets.

Investments are needed in energy efficiency and carbon mitigation in sectors / industries currently with a high carbon footprint which need to operate for an orderly transition, along with continuous greening through annual energy efficiency / carbon reduction targets. These targets could be enforced using carbon pricing and allocation of emission ceilings across sectors to incentivize decarbonization.

MANAGING DEMAND SHIFTS AND NEAR-TERM UNIT COST INCREASES

The analysis suggests that demand for certain goods will change during the energy transition along with the capital and operating expenditures of companies. Interventions on both the supply side and the demand side could help mitigate these effects:

Building awareness and transparency around climate risks and opportunities

As organizations navigate the net zero transition, they stand to benefit from identifying the risks and opportunities associated with physical climate hazards and transition impact. Formal efforts to gauge climate risks are expanding. Among other things, financial regulators, including the Bank of England and the European Central Bank, are mandating climate-risk stress tests for financial institutions[7].

Anticipating future competitive dynamics and making adjustments

As the basis of competition is altered, companies may need to overhaul their portfolios and business models and identify new areas of opportunity in a net zero economy. Governments would similarly need to consider exposing their economies to the transition and seize opportunities to benefit from it. In a fast-changing world, given the imperatives of transition, all businesses, especially those that are more vulnerable with a higher carbon footprint across the value chain, need to carefully calibrate their future strategies to ensure compliance with emerging transition requirements, as well as the sustenance of their businesses.

Lowering technology costs with R&D

Some existing technologies that will be needed to achieve a net zero economy by 2050 are not yet cost competitive when compared to the entrenched high-carbon technologies. Technology gaps remain. R&D investments can help bring down technology costs, and various support models exist. In the United States, for example, the Department of Energy's National Laboratories partner with private companies to drive R&D[4].

Nurturing industrial ecosystems

To produce low-carbon technologies at a cost that permits their broad uptake, companies may need to develop capabilities through partnerships that are not part of existing value chains or through new business ecosystems. Governments need to consider the role they might play in creating policy environments that are conducive to the formation and functioning of such ecosystems.

Identifying measures to manage cost increases

Organizations can identify a range of compensating mechanisms in cases where decarbonization actions increase costs and can understand which measures work best under different sets of circumstances and constraints. Examples include identifying opportunities to distribute the impact of cost increases along the value chain, partnering with suppliers to lower costs, and, where feasible, charging consumers a "green premium" or otherwise including this as part of the value proposition.

Sending demand signals and creating incentives

Markets for emerging and still-expensive low emissions technologies are often too small and unpredictable for manufacturers to achieve economies of scale. Interventions to lift demand can lessen market risk and create long term certainty that encourages manufacturers to add production capacity.

ESTABLISHING COMPENSATING MECHANISMS TO ADDRESS SOCIO-ECONOMIC IMPACT

The uneven impact of the net zero transition could be substantial and prove to be a major stumbling block if stakeholders feel that they are not protected from risk or given support to pursue cleaner opportunities. The public and private sectors could consider taking the following measures to help the adjustment to uneven impact:

Supporting economic development and diversification

Individual regions could develop new low emissions industries as demand wanes for fossil fuels and carbon intensive industries. Some countries possess the natural capital to do so, such as forest rich countries that can promote reforestation to sequester carbon, create jobs, and secure financial inflows. Others will want to consider options for developing the technological, human, and physical capital to create these new sectors.

Enabling reskilling and redeployment of workers

Retraining workers for new tasks and ensuring that new entrants in the workforce have the right skills for the jobs needed in a low carbon economy can help promote an inclusive transition.

Instituting support programs (including insurance) for workers and consumers

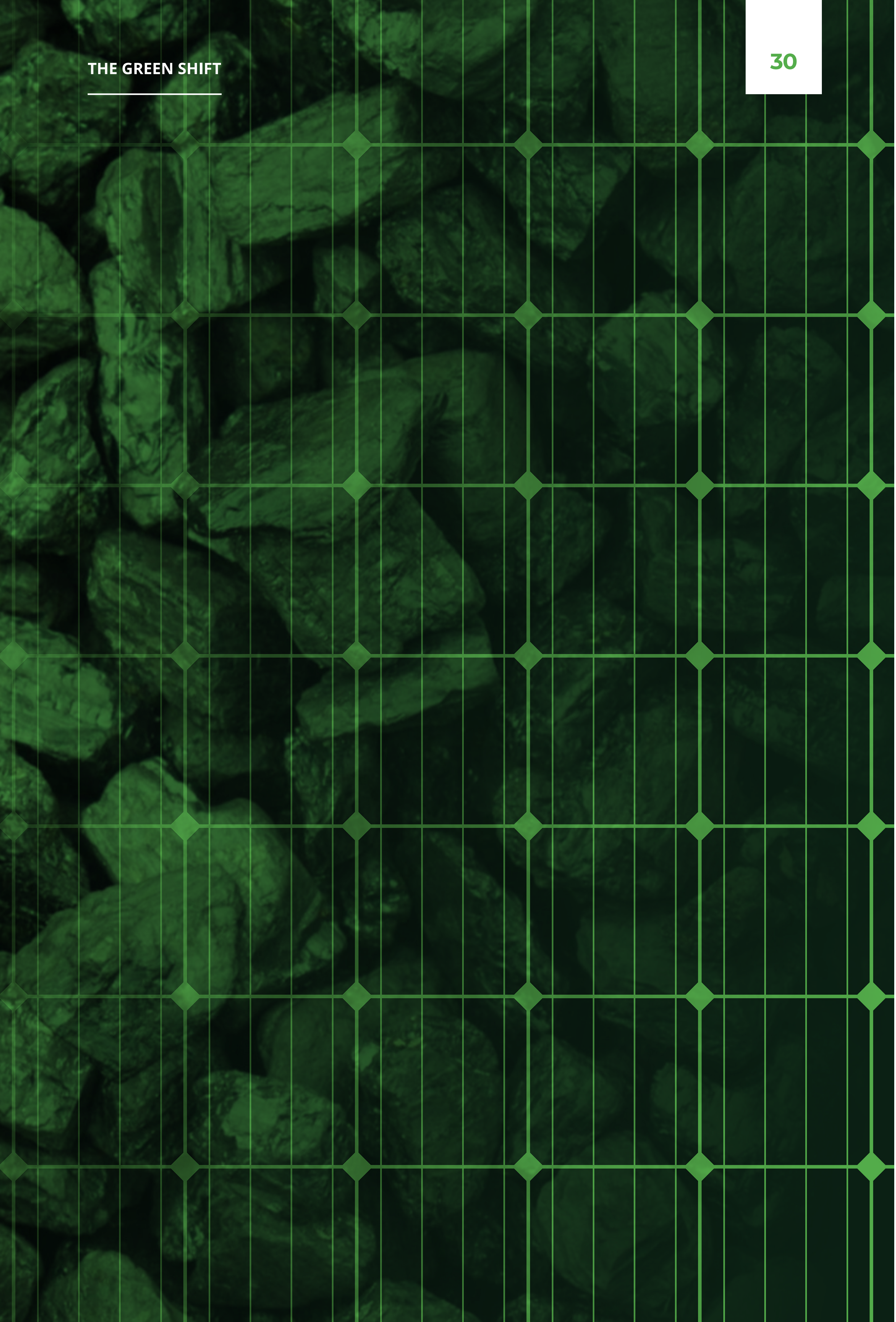
Options for aiding displaced workers include income support measures like unemployment protection and cash transfers, which can support workers in retraining and finding jobs. Subsidies and other programs could also help consumers, especially from low income households, if the transition brings higher upfront capital expenditures or increases energy prices.

CONCLUSION

India is among the few countries on track to achieve its 2030 climate commitments as part of the Paris Agreement. More needs to be done, however, as India still ranks as third highest CO_2 emitter in the world. The effects of climate change are being felt in India and around the globe, and the risk is likely to be aggravated if timely measures are not taken.

India currently emits ~3.7 $GtCO_2e$ per annum, most of which comes from the industrial and power sectors. Decarbonizing these sectors and shifting to renewable power generation, electrification of heating in industries, clean fuels (such as hydrogen), better energy efficiency, and circularity in plastics will be the way forward for India.

For India to effectively support overall decarbonization efforts, change must happen along capital reallocation, demand shift management and compensation mechanism.



Chapter 3

ENERGY TRANSITION PLANS OF DOMESTIC PUBLIC SECTOR OIL & GAS MAJORS

In this section

UPSTREAM OIL MAJORS

OIL & NATURAL GAS CORPORATION (ONGC)

BASELINE

9.41 MMTCO_2E

NET OPERATIONAL EMISSION (FY 2021-22)

TARGET

0.0 MMTCO_2E

NET OPERATIONAL EMISSION (2050)*

* aspirational target

ROADMAP TO NET ZERO

The Company has a dedicated Carbon Management & Sustainability Group which is the nodal point for all activities pertaining to Energy Transition and Emission Reduction. The Group has a specialized Cell which is guiding the company's Net Zero Strategy.

While GHG accounting (Scope-1 & 2) is carried out every year through in-house experts, these are being verified through a third party agency since 2019-20.

ONGC is aspiring to achieve Net Zero Emissions by 2050. With this overall vision, it is in the process of conducting a scientific study for setting total Emissions Targets and strategies for achieving Net Zero by 2050.

The study will cover scope-1, scope-2 and scope-3 emissions of the company by taking into account all the seven types of Greenhouse Gases followed by projection of anticipated emissions of the company at the end of the target year and emission reduction pathways.

The study is broadly split into two phases comprising of accounting of emissions in Phase -1 and the GHG Abatement and Offset Strategy and net zero emission targets in phase-2.

It is also envisaged that emission measurements shall be integrated with GHG Accounting in SAP to provide real time measurements.

In addition to various efforts under way to reduce emissions by reducing Gas flaring, use of RE, Energy Efficiency Measures, promoting Green Buildings and paperless office, ONGC is also taking proactive measure to sensitize its workforce of the need to combat climate change and facilitate energy transition by organizing regular Trainings, Workshops, seminars and webinars in association with reputed bodies like IIT, Mumbai, CII, IEA, UNGC etc.

As the country's premier National Oil Company, ONGC is cognizant of its role in driving energy transition and promoting innovative solutions like CCUS in EOR, Geo thermal energy and offshore wind.

Considering the role of CCUS / CCS technologies in decarbonisation and climate change mitigation, most international bodies like IPCC, IEA, etc. expect E&P companies to play a pivotal role in using these technologies. IEA considers CCUS as one of the four pillars of global energy transformation, the others being RE based electrification, bio-energy & Hydrogen. Using CO_2 for Enhanced Oil Recovery is a proven technology and leads to increase in oil recovery, however the high cost of capital has been a significant barrier in its widespread application.

ONGC has also recently signed an MoU with Equinor which includes activities in areas of low carbon and renewables like Carbon Capture Utilization and Sequestration (CCUS) opportunities, Offshore Wind and / or solar & solar-hybrid projects in India, green and blue hydrogen and Ammonia.

Photo Credit: Adobe Stock

OIL & NATURAL GAS CORPORATION (ONGC)

STRATEGIC TRANSITION INITIATIVES

Renewable Energy

ONGC's total energy generation capacity was 922 MW, of which renewable energy accounted for 184 MW and gas turbine power generation at various locations accounted for 738 MW.

Different groups within ONGC undertake renewable energy related activities as per requirement. These include the RE cell (Technical Services), Business Development & Joint Venture (BD & JV), ONGC Energy Centre (OEC) for solar (PV & Thermal), On-shore wind, Off-shore wind, Hydrogen, Biofuel, Geothermal, Helium etc.

ONGC plans to shift completely to renewable energy for Scope 1 consumption with a 10 GW target by 2040 of renewable energy capacity being set. ONGC has entered into an MoU with NTPC for setting up a joint venture company for the renewable power business. ONGC has also signed an MoU with Solar Energy Corporation of India (SECI) for renewable energy projects. The feasibility to generate renewable energy more than 1.5 times of its Scope-2 energy consumption is being examined. A pilot geo-thermal project at Puga Valley, Ladakh with a capacity of 1 MW and tentative investment of Rs 38 Cr has been taken up and is expected to be completed by FY23.

Green Hydrogen

ONGC Energy Centre (OEC) is taking up a pilot scale metallic system project to produce 90 MTPA of Hydrogen at MRPL. The project is expected to be completed by 2025 with an anticipated investment of around Rs. 180 Cr.

Carbon Capture, Utilization & Storage

The Company is fully cognizant of its role in leading the energy transition in the country as the premier national oil company (NOC) and promoting innovative solutions like CCUS in EOR, Geo thermal energy and offshore wind.

ONGC in association with IOC is working on India's first industrial-scale carbon capture project at Koyali refinery where the CO_2 captured at Koyali would be treated, compressed and transported through pipelines to Gandhar oil field of ONGC. The CO_2 would be injected into the depleted oil field and would ensure utilization and permanent storage of CO_2 besides an increase in oil production. The project has the potential for oil gain of 10% and the estimated cumulative sequestrated quantity is 5 to 6 million tons of CO_2 by the year 2040.

OIL & NATURAL GAS CORPORATION (ONGC)

STRATEGIC TRANSITION INITIATIVES

Other Major Efforts

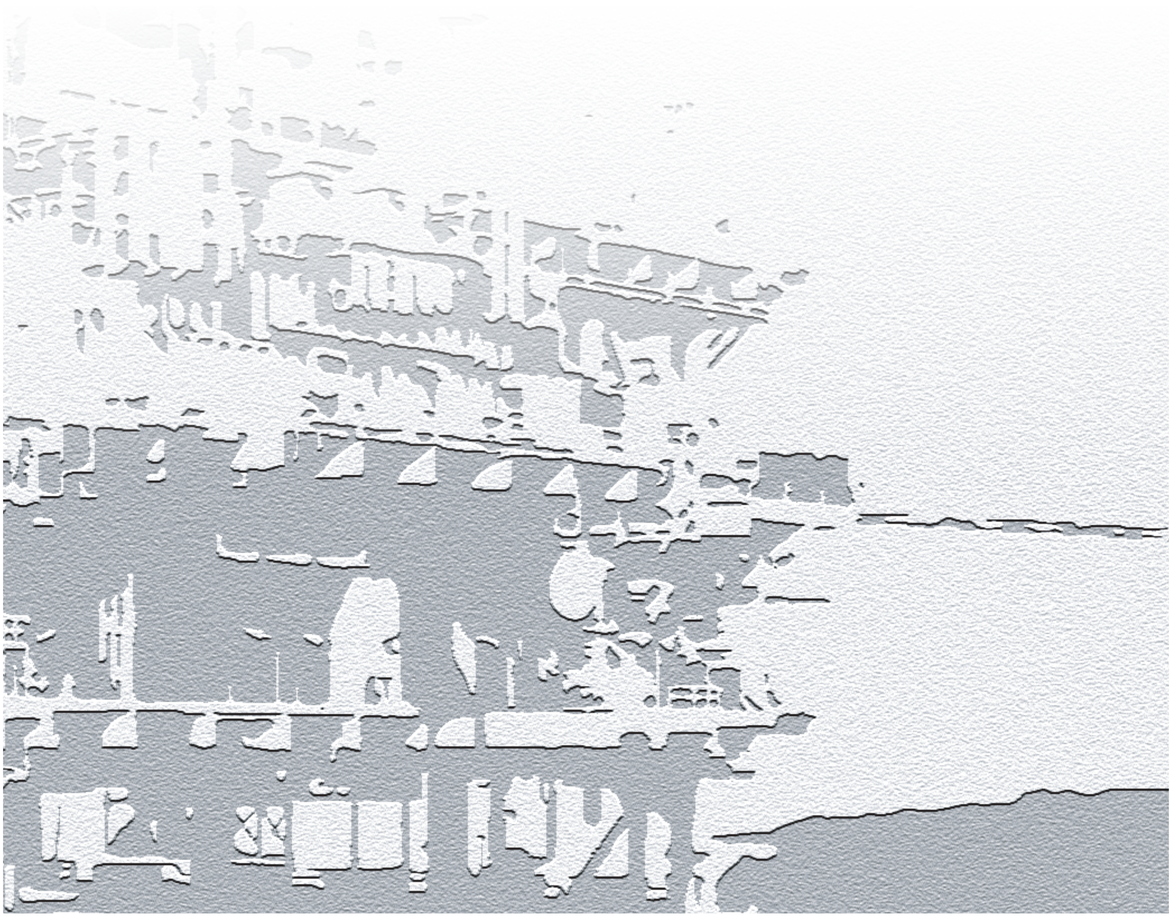
ONGC has signed MoU with Equinor for jointly working in the areas of low carbon solutions in India like CCUS, off-shore wind, solar, wind-solar hybrid, green & blue hydrogen and ammonia.

ONGC and NTPC have carried out pre-feasibility study for a demonstration off-shore wind power project in India with possibility to produce green hydrogen. Pursuant to this, further discussions would be undertaken with MNRE for obtaining necessary concessions for development of offshore wind plants.

ONGC is planning to leverage the carbon markets by adopting Kyoto Protocol for sustainable development and generating carbon credits through the CDM projects. ONGC also plans to generate Emission Reduction Certificates for revenue generation / offsetting.

The company would be accounting material Scope 3 emissions, and develop strategies for aggressive reduction in value chain emissions.

ONGC has 5 EVs each for OVL & its Delhi HQ with suitable charging infrastructure.



OIL INDIA LIMITED (OIL)

BASELINE

0.21 MMTCO$_2$E

NET OPERATIONAL EMISSION (FY 2021-22)

TARGET

TO BE FIRMED UP

ROADMAP TO NET ZERO

The total emssions are projected to be reduced by 15% before FY40 including various project and capacity expansions. OIL also sees CO_2 reduction of 0.27 MMTCO2e through renewable energy generation, making them carbon positive.

OIL deals with exploration and production of crude oil and natural gas. Most of the exploration activities like survey, drilling etc. are conducted in remote locations for a very short duration of 3 to 4 months. Generally portable Generating units of 1 MW (approx) capacity each are used. But the activities related to production and transportation are generally conducted in a fixed location for a long term.

It is observed that till now large-scale portable green energy systems have not been deployed, although, considering the R&D activities going on presently, there is a possibility that such systems shall be available in future.

The company uses fossil fuel (HSD) vehicles of different types. These vehicles are a major contributor to the emission of carbon to the atmosphere. These vehicles may be initially converted to CNG as a transition fuel and then gradually to more cleaner fuels like green hydrogen Fuel Cell or EV.

Hence, it is suggested that transition strategy may be short-term, covering the next 10 to 20 years and long-term, covering the next 30 to 50 years.

As a part of short-term transition strategy, the company shall try to replace the smaller engines, vehicles etc. running on HSD with natural gas or CNG to alternative green fuels like green hydrogen, batteries, etc.

In the long term, OIL may plan to replace the equipment in different static installations running on fossil fuels with new equipment running on alternative fuels depending on emergence of new technologies.

Table-3.1: Decadal reduction in carbon footprint

Decade	% Carbon Reduction	Activities Planned
2020-30	5%	Replacement of vehicles with CNG, EV & Hydrogen fuel cell
2030-40	15%	Replacement of vehicles, small engines with CNG, Biogas, EV & Hydrogen fuel cell
2040-50	20%	Use of blended natural gas as per recommendation
2050-60	20%	Use of blended natural gas as per recommendation
2060-70	40%	Use of green energy in all activities

OIL INDIA LIMITED (OIL)

STRATEGIC TRANSITION INITIATIVES

Renewable Energy incl. Biofuels

OIL forayed into the renewables in FY12. The total capacity established includes 174.1 MW of wind power in Rajasthan, MP & Gujarat (1,138 Cr investment) and 14.0 MW in solar power in Rajasthan (92.5 Cr investment). OIL intends to develop renewable energy projects in future based on market conditions and policy support.

Green Hydrogen

OIL is setting up a green hydrogen pilot plant at Assam to study the possibility of enhancing the calorific value of Natural Gas through blending and to assess the impact of blended gas on existing infrastructure. OIL is looking for opportunities to promote indigenous start-ups for the development of green hydrogen technology. OIL has initiated collaborative research in bio-hydrogen with the University of Petroleum and Energy Studies (UPES), Dehradun.

Carbon Capture, Utilization & Storage

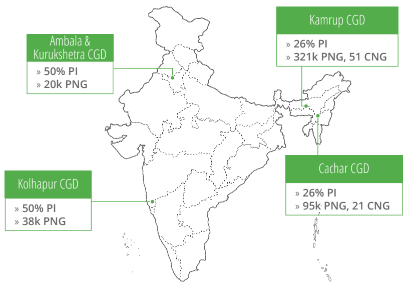
OIL has signed an MoU with IOCL for capturing CO_2 from flue gas at the Digboi Refinery. The captured carbon will be utilized for EOR activities. OIL also plans to capture non-associated (pure) CO_2 generated at BCPL from the gas it receives as feedstock from OIL. Further, OIL has tied up with the Centre of Excellence in Carbon Capture and Storage (COE CCS), established in IIT Bombay, for an R&D effort.

Other Major Efforts

OIL has formed two joint venture companies (HPOIL Gas Pvt Ltd in Nov 2018 with HOCL and Purba Bharati Gas Pvt. Ltd in Nov 2019 with AGCL & GAIL) through which multiple City gas distribution (CGD) operations are active in India.

Exhibit-3.1: City Gas Distribution Projects of OIL in India

S. No.	Name of Gas	Estimated CAPEX (in Rs. Cr.)	OIL's commitment (in Rs. Cr.)	OIL's share of equity (in Rs. Cr.)	Total equity share (in Rs. Cr.)
1	Ambala & Kurukshetra	333.50	166.75	50.03	96.10
2	Kolhapur	307.16	153.58	46.07	
3	Cachar	727.72	189.20	63.55	228.54
4	Kamrup	1,889.23	491.20	164.99	
	TOTAL	3,257.61	100.73	324.64	324.64



DOWNSTREAM OIL MAJORS

INDIAN OIL CORPORATION LIMITED (IOCL)

BASELINE

21.54 $MMTCO_2E$

NET OPERATIONAL EMISSION (FY 2021-22)

TARGET

0.0 $MMTCO_2E$

NET OPERATIONAL EMISSION (2046)

ROADMAP TO NET ZERO

IOCL (standalone) witnessed emission of 21.54 $MMTCO_2e$ of total emissions in FY22 primarily from its refinery & petrochemical business (~97%), of which Scope 1 emissions account for 96.5% and Scope 2 for 3.5%. Including its subsidiary Chennai Petroleum Corporation Limited (CPCL) refinery at Chennai, IOCL's (Group) emissions exceed 24 $MMTCO_2e$. With planned expansions, IOCL's emissions are projected to cross 40 $MMTCO_2e$ by FY30.

The Corporate emission accounting is done by in-house team within the Alternate Energy & Sustainable Development Group in IOCL. The company's refinery & petrochemical plants have been independently undertaking ISO 14064 certification. At the corporate level, IOCL is in the process of getting its GHG inventory (Scope-1, 2 & 3 validated through third-party. IOCL is also undertaking efforts to digitalise its GHG accounting and net zero impact monitoring process.

IOCL avoided 3.36 $MMTCO_2e$ emission in FY22 by implementing measures such as switch to natural gas, promoting pipeline transport, energy efficiency, sourcing renewable power and plantation of trees.

IOCL has identified a two-way strategy to achieve net zero footprint. The company has estimated that more than half of its exisitng emissions can be mitigated through process efficiency, fuel replacement and gridification efforts. The balance 40%+ of its emissions would need to be mitigated through carbon negative technologies such as CCUS & tree plantation or through generation & purchase of carbon credits.

A phased timeline has been outlined for the implementation of the recommended measures (Exhibit 3.'2).

Exhibit-3.2: Phased implementation roadmap to net zero by IOCL

SHORT TERM 1-2 Years

- GHG Inventory - Equity Approach
- Firming up Mitigation Targets, Plans & Phase Targets
- Energy Efficiency Projects
- Renewable Energy Projects

MEDIUM TERM 2-5 years

- Energy Efficiency Projects
- Switch to Natural Gas
- Increasing Grid Imports
- Renewable Energy Projects
- Tree Plantation
- CCUS

LONG TERM 5-10 Years

- Process Efficiency
- Green Hydrogen
- Natural Gas to CBG
- Increasing Grid Imports
- Renewable Energy Projects
- Tree Plantation
- CCUS

NATURAL INVESTMENT CYCLE >10 years

- Process Efficiency
- Green Hydrogen
- Natural Gas to CBG / Green Hydrogen
- Increasing Grid Imports
- Renewable Energy Projects
- Tree Plantation
- CCUS
- Carbon Markets

INDIAN OIL CORPORATION LIMITED (IOCL)

STRATEGIC TRANSITION INITIATIVES

Renewable Energy (Solar / Wind)

With an investment of 1,400 Cr, IOCL generated 358 GWh of renewable power in FY22 with 74% coming from wind power and 26% from solar PVs. 19,502 retail outlets have been solarized and 111.5 MW in cumulative capacity has been developed through solarization. The company continues to expand its solar portfolio. 6.34 MW capacity projects are currently under execution and feasibility assessment has been completed for additional 19 MW at various locations. A high-level committee has been setup to analyze various options for further expansion.

IOCL has formed a JV with NTPC to establish a 650 MW hybrid renewable power plant for sourcing round-the-clock RE power for upcoming projects (by Oct '24). This would include setting up of 2.1 GW solar, 0.6 GW wind and 6 GWh pump hydro storage.

Green Hydrogen

IOCL's current hydrogen generation stands at 556 KTPA, with planned expansion upto 825 KTPA. Efforts are being made to shift from Grey to Green Hydrogen in line with GoI targets. IOCL is partnering with L&T and Renew Power for production of Green Hydrogen. L&T is also assisting IOCL in manufacturing of electrolyzers to be used for production of Green Hydrogen.

Carbon Capture Utlization & Storage

IOCL is undertaking multiple projects with the largest being a Rs. 4,500 Cr project with ONGC where CO_2 would be captured fom the company's Gujarat Refinery and transportation & carbon sequestration would be carried out by ONGC. Additional Rs. 600-1,000 Cr investment is expected for CCUS projects at Panipat & Paradip.

Biofuels

IOCL is targeting 20% ethanol blending in petrol by 2025 (10% at present) and 5% biodiesel blending in HSD by 2030. LOIs have been issued to entrepreneurs for production of 23.84 Cr Litres of biodiesel from used cooking oil (UCO). Production has commenced from 3 plants.

A 100 KLPD 2G ethanol plant with an investment of Rs 909 Cr was dedicated to the nation by the Hon'ble Prime Minister of India on World Biofuel Day, 10th August 2022. The plant is expected to result in carbon mitigation of 38 TMTCO$_2$e per annum. IOCL is partnering with Praj & LanzaJet to promote biofuels as Sustainable Aviation Fuel (SAF).

...contd. on next page

INDIAN OIL CORPORATION LIMITED (IOCL)

STRATEGIC TRANSITION INITIATIVES

Biofuels

2,247 LOIs (5.5 MMTPA capacity) have been issued to entrepreneurs for setting up Compressed Biogas (CBG) plants. 18 plants have been set up so far. Sales have commenced from 30+ retail outlets, under the brand name 'IndiGreen'. A biofuels complex is being set up at Gorakhpur, UP to produce CBG from paddy straw.

Exhibit-3.3: IOCL CBG projects - Implementation Timeline

SHORT-TERM OUTLOOK
6 - 12 months

- 100 TPD cattle dung based CBG Plant at Jaipur
  Commissioning: August 2022
- 200 TPD paddy straw based CBG Plant at Gorakhpur
  Commissioning: August 2022
- Formation of JVC with Verbio, Germany for 40 biomass based CBG plants
- Formation of JVCwith Poonawala Clean Energy and Noble Exchange for 100 MSW based CBG plants
- Marketing of fermented organic manure through IndianOil RO / NAFED channels
- Commissioning of additional 10 plants under SATAT

MEDIUM-TERM OUTLOOK
12 - 36 months

- Commissioning of additional 100 CBG plants under SATAT
- Setting up 10 large scale CBG plants through JVCs, with biomass, municipal waste, press mud etc as feedstock
- CBG (6.5 TPD) to Green Hydrogen (2 TPD) plant at Gorakhpur, Uttar Pradesh
- Creating a business vertical for manure marketing in India
- Manure to be enriched using additives developed by R&D (field trials ongoing)
- Manure marketing through IndianOil Channels, Fertilizer Marketing Company, Farmer Producer Companies, HURL etc.

Other Major Efforts

- IOCL has ventured into Aluminium-Air battery space through a joint venture with Israel based e-mobility company 'Phinergy Limited'. The company has installed 2,145 EV charging stations & 34 battery swapping units, with a target to install 10,000 EV charging stations in the next 3-5 years.
- Eco-friendly Waste Plastic to Fuel Technology 'INDEcoP2F' developed.
- Development & demonstration of commercially viable fuel cell buses based on hydrogen produced from multiple pathways.
- IOCL aims to be a significant contributor in the national goal of increasing Natural Gas's share in energy mix to 15% by 2030. Last year, IOCL sold 5.68 MMT of NG. The company is undertaking various projects to increase infrastructure.
- Invested over Rs. 17,000 Cr to deliver cleaner BS-VI petrol / diesel in India.
- Promoted sale of LPG which in turn leads to reduced felling of trees & lower indoor pollution.
- Launched premium variants for gasoline (XP95/XP100) with 44% lower CO & 13% lower hydrocarbon emission. Xtragreen diesel provides fuel economy benefits of 5-6% and reduction in PM, CO & NO_x by 7%, 12% & 5% respectively.
- Differentiated LPG products, Indane Nanocut & XTRA TEJ developed for high temperature industrial applications.
- Green Combo lubricants (combining engine, gear and axle oil) introduced for heavy duty segment - providing improved fuel economy (~4 to 5%) & significant emission reduction.

BHARAT PETROLEUM CORPORATION LIMITED (BPCL)

BASELINE

9.50 $MMTCO_2E$

NET OPERATIONAL EMISSION (FY 2020-21)

TARGET

0.0 $MMTCO_2E$

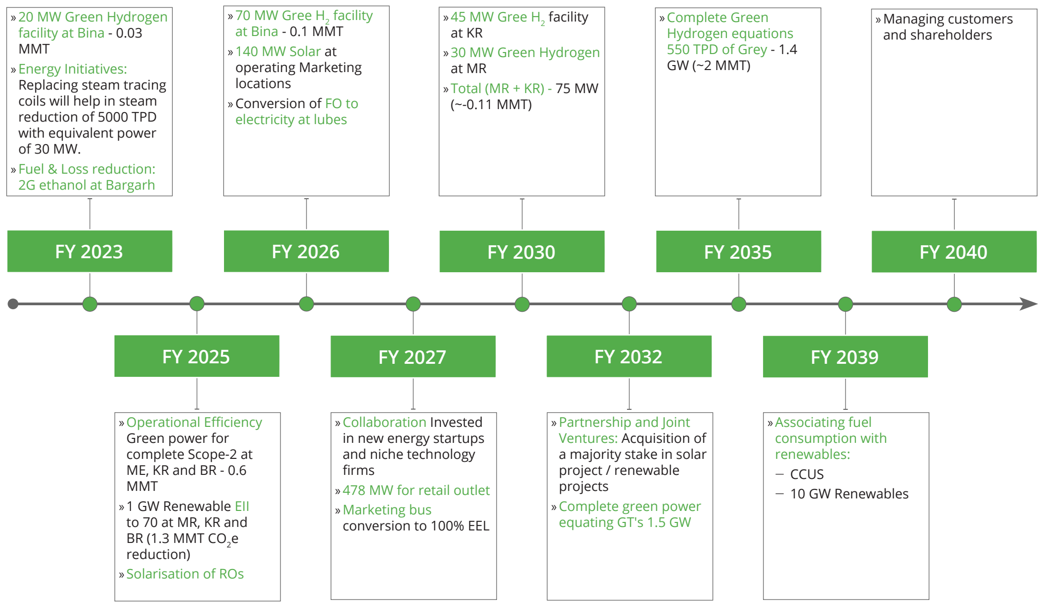
NET OPERATIONAL EMISSION (FY 2039-40)

ROADMAP TO NET ZERO

BPCL had a GHG inventory of 9.5 $MMTCO_2e$ primarily from DG sets, fire engines, company owned vehicles, process stacks, power purchase from third parties (SEB, private etc) and emissions created during production processes involved in refineries, petrochemicals, & marketing operations, of which Scope 1 emissions account for 89.5% and Scope 2 for 10.5%. This is projected to reach 12.4 $MMTCO_2e$ by FY30 including various project and capacity expansions in the absence of mitigation measures.

BPCL aims to reduce target emissions by FY30 from 12.4 to 9.8 and achieve net zero by FY40. To achieve the same, BPCL has outlined a multi-year roadmap combining increased operational efficiency and collaborations with investments in renewable power, biofuels, Carbon Capture, Utilization and Storage (CCUS) and green hydrogen generation (Exhibit 3.4).

Exhibit-3.4: Phased implementation roadmap to net zero by BPCL



BPCL	2019-20	2024-25	2026-27	2029-30	2031-32	2034-35	2039-40
Total Scope ($MMTCO_2e$)	9.8	7.5	11.5	9.8	7.5	5.5	0

BHARAT PETROLEUM CORPORATION LIMITED (BPCL)

Renewable Energy (Solar)

BPCL is building a portfolio of solar projects, expected to reach 1 GW capacity by 2024 and 10 GW by 2040 (Exhibit 3.5). A total of 2,554 retail outlets have been solarized, with target to reach 12,554 by FY25 and 100% retail outlet solarization by FY30. Dealers have been provided with a subsidy to incentivize the solarization. Vanadium Redox Flow battery with expected capacity of 1 MWh and 20-25 years life is being evaluated to enable the availability of round the clock RE power, with the demonstration plant to be setup by Q2 of 2023.

Exhibit-3.5: Solar Power portfolio of BPCL

Land Parcels	Area (Acres)	Solar plant capacity (MW)	Estimated Date of Completion
Bina, Madhya Pradesh	40	14	30.09.2022
Badnera, Maharashtra	20	7	15.12.2022
Tadali, Maharashtra	36	12	31.12.2022
Sanganer, Rajasthan	40	15	15.12.2022
Karoor, Tamil Nadu	100	35	31.12.2022
Kochi, Kerala	270	90	31.01.2023
Prayagraj, Uttar Pradesh	393	130	31.12.2023
Padariya, Madhya Pradesh	2,100	700	30.11.2024
TOTAL	**2,999**	**1,003 (1 GW)**	**By 2024**
Future	-	10 GW	By 2040

Biofuels

BPCL has achieved over 10% ethanol blending and targeting to contribute significantly towards the national objective of 20% blending by FY26 with an estimated reduction of 21.74 $MMTCO_2e$ of GHG.

BPCL acts as the industry coordinator for ethanol. 131 long-term off-take agreements (production capacity of 432 Cr L of ethanol per annum) have been signed between OMCs and upcoming ethanol plant owners. EOIs are being floated to entrepreneurs for supply of biodiesel from Used Cooking Oil (UCO) from existing and/or new plants.

A 100 KLD integrated 1G & 2G bio-ethanol production plant is being developed by BPCL in collaboration with Praj & Tata Consultancy Engineers at an investment of Rs. 1,607 Cr. The scheduled mechanical completion of the plant would be Mar-Jun 2023. The feedstock for 1G ethanol is rice grain & for 2G ethanol is rice straw.

EOIs for production of CBG and Bio-manure are being floated under the SATAT scheme. 7 plants have started producing CBG. LOIs have been issued for 299 plants with an installed capacity of 1,265 TPD. BPCL aims to produce 3 MMT of CBG by FY24 from 1,000 CBG plants through the LOIs issued under SATAT. The possibility of setting up model plants are being explored based on availability of feedstock, land, and potential off-take of CBG and by-products.

BHARAT PETROLEUM CORPORATION LIMITED (BPCL)

STRATEGIC TRANSITION INITIATIVES

Green Hydrogen

BPCL is undertaking efforts to establish a 20 MW Green Hydrogen Plant at Bina, expected to be commissioned by Mar '24. The company has partnered with ACME, Greenko and ReNew Power for exploring opportunities and setting up 1.9 TPD Green Hydrogen based H-CNG refueling station at Ahmednagar, Maharashtra. R&D on Green Hydrogen production from agricultural / organic waste is planned in Punjab / Haryana for blending in CGD networks.

As a step towards "Atmanirbhar Bharat", BPCL's R&D Centre has collaborated with Bhabha Atomic Research Centre (BARC), to establish an ecosystem for indigenous electrolyser technology development & manufacturing with cost competitive electrolyser technology. The fabrication & demonstration of the modular unit is expected to be completed by Dec '24.

Carbon Capture, Utilization & Storage (CCUS)

BPCL aims to implement Simulated Moving Bed Absorption (SMB) technology for CCUS, with lab level pilot trials planned for Mar'24 and refinery implementation by Mar'26. The SMB process has excellent heat integration with 10-25 times lesser energy requirements and 50-70% capture cost reduction compared to other technologies.

BPCL is supporting scale-up of CO_2 to methanol/DME technology being developed by Breath Applied Science Pvt Ltd, a start-up incubated at JNCSAR, Bengaluru. Pilot plant trials conducted in Apr '21 saw CO_2 conversion (29.5%) with Methanol selectivity in range of 40-45%.

BPCL CRDC is working on Solid Oxides Electrolyzer Cell (SOEC) based co-electrolysis process for CO_2/H_2O conversion to syngas and subsequent conversion of syngas to produce green methanol. Trials at lab scale are planned for Jun'24, and refinery implementation by Mar'26. Production of Sustainable Aviation Fuel (SAF) from captured CO_2 and using green hydrogen is also being explored as a promising alternative, with BPCL aiming to set up a demonstration plant by Dec 2026.

EV charging and swapping stations

BPCL aims to establish 200 fast charging corridors by FY25 covering national & state highways connecting major cities, tourist locations and economic centers. BPCL is also aiming to set up 3,000 EV charging and 200 battery swapping stations by FY25.

Strategic partners like Ola Electric, Race Energy, Infinity & Hero have been brought on board to establish fast charging & battery swapping pilots across India.

HINDUSTAN PETROLEUM CORPORATION LIMITED (HPCL)

BASELINE

4.61 MMTCO_2E

NET OPERATIONAL EMISSION (FY 2019-20)

TARGET

0.0 MMTCO_2E

NET OPERATIONAL EMISSION (2040)

ROADMAP TO NET ZERO

HPCL had a GHG inventory of 4.61 MMTCO_2e (Scope 1 & 2) in FY20, primarily from combustion of fuels in furnaces, boilers, IC Engines, Hydrogen Generation, flaring from refinery operations, purchased electricity consumption etc. Scope 1 emissions account for 84.8% of total emissions and Scope 2 accounted for the balance 15.2%. This is projected to reach 10.1 MMTCO_2e by FY40 under Business-as-Usual Scenario with capacity expansions. HPCL aims to achieve net zero Scope 1 & Scope 2 emissions by tne year 2040. Boston Consulting Group has been engaged for the development of environment strategy & roadmap including the net zero plan by September 2022. The identified elements of the net zero strategy have been presented in Exhibit- 3.6.

Exhibit-3.6: Key elements of roadmap to net-zero by HPCL

HINDUSTAN PETROLEUM CORPORATION LIMITED (HPCL)

STRATEGIC TRANSITION INITIATIVES

Renewable Energy (Wind / Solar)

HPCL has a target of generating 2.4 GW by 2025 and progressively increasing that to 10 GW by 2030. HPCL has total renewable capacity of 155 MW, where wind power ~101 MW capacity & solar power ~54 MW capacity. 100% solarization of retail outlets is also targeted with 32% completed as of March 2022.

Biofuels

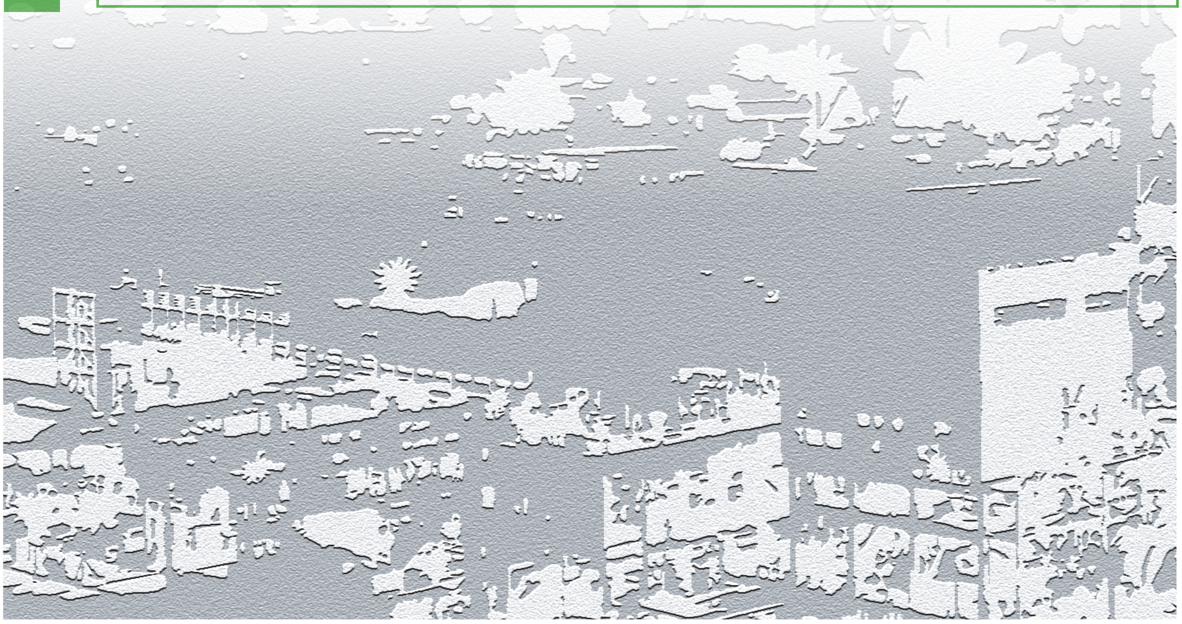
HPCL achieved 9.03% of ethanol blending in FY 2021-22 and targeting 20% ethanol blending by FY 26. HPCL also blended 2308 KL biodiesel in HSD in FY 2021-22.

HPCL has a 100% owned subsidiary named as "Hindustan Biofuels Ltd"(HBL). HBL was promoted as a backward integration initiative to enable HPCL's foray in manufacturing of ethanol for blending in Petrol. HBL has two integrated Sugar -Ethanol-Cogeneration plants at Sugauli and Lauriya districts in the state of Bihar.

HPCL is foraying into bioethanol production by setting up 2G technology based bio refinery at Bathinda. In addition, HPCL is also planning to put up 1G ethanol plant at multiple locations across India with total capacity of ~123 TMTPA.

HPCL is executing a compressed biogas plant with project cost of Rs. 133 Cr at Budaun(UP) which will be producing CBG up to 14 tonnes per day. For further expansion in CBG capacities, additional CBG plant with capacity of over 6 TMTPA has been planned.

EOIs for production of compressed biogas are being floated under the SATAT scheme, with a target to setup 1,000 plants by FY24. 413 LOIs have been released with a capacity of 2,261 TPD (825 TMTPA) as of Mar '22.



HINDUSTAN PETROLEUM CORPORATION LIMITED (HPCL)

STRATEGIC TRANSITION INITIATIVES

Green Hydrogen

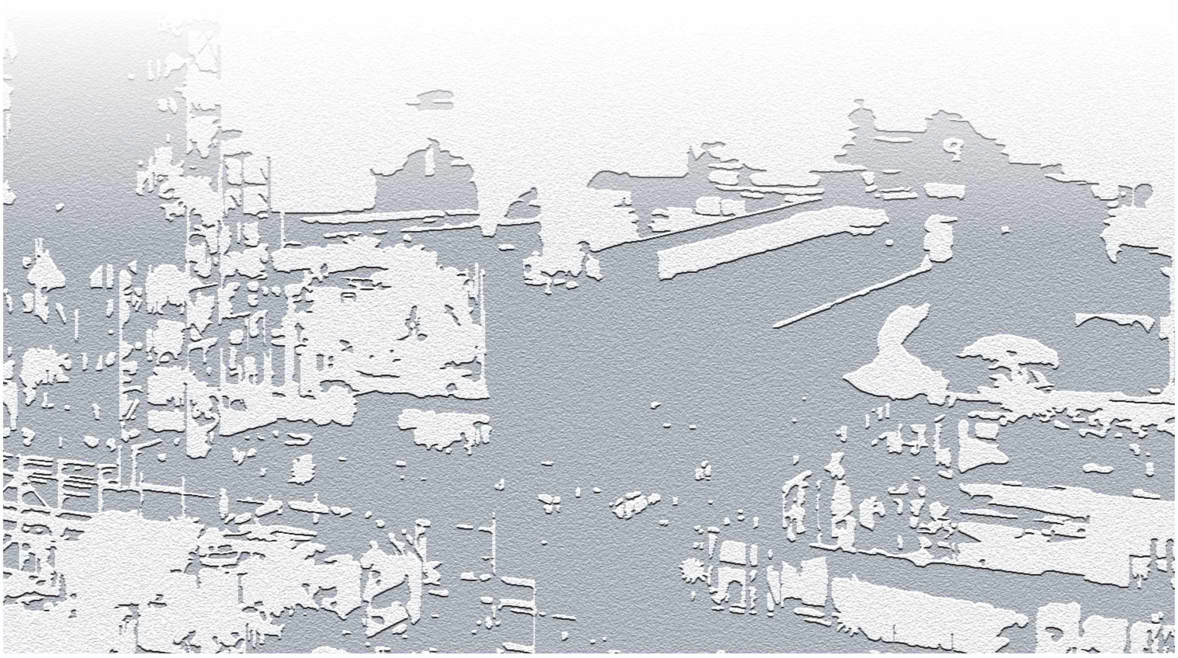
HPCL has increased usage of hydrogen in refineries for fuel quality improvements to BS-VI and for residue hydrocracking for conversion of fuel oil to distillate. At HP Green R&D Centre, Bengaluru only Green Hydrogen is being used. HPCL is setting up a green hydrogen project capacity of 370 TPA (2.6 MW) at Visakh Refinery which is expected to be commissioned by Jan 2023.

Carbon Capture, Utilization & Storage (CCUS)

HPCL is planning to install a 24 KTPA CO_2 capture unit in Visakh at a cost of 17 Cr, based on inhouse R&D technology. The unit will capture CO_2 from HGU reformer off-gas and is expected to be completed by Dec 2023.

Other Major Efforts

Several energy efficiency improvement measures such as flare gas recovery, staged flare, parallel reformers, integration of VDUs, vacuum pumps in VDUs, helical / Packinox Heat Exchangers etc. have been undertaken at the refineries leading to a reduction of the CO2 footprint. As of Mar 2022, 1011 EV charging stations have been setup across the country by HPCL. HPCL aims to have 5,000 EV charging stations and battery swapping stations over 3 years.



GAS MAJORS

GAS AUTHORITY OF INDIA LIMITED (GAIL)

BASELINE

3.72 MMTCO_2E

NET OPERATIONAL EMISSION (FY 2020-21)

TARGET

0.0 MMTCO_2E

NET OPERATIONAL EMISSION (2040)

ROADMAP TO NET ZERO

GAIL had a GHG footprint of 3.72 MMTCO_2e of total emissions in FY21 primarily from use of NG as fuel (contributing to 56% emission). In total, Scope 1 emissions accounted for 89% of the emissions and Scope 2 accounted for 11% of the emissions. Emissions are projected to reach 5.47 MMTCO_2e by FY40 including various project and capacity expansions.

GAIL is further committed and has already embarked on its Net-Zero journey through science based ambition and action plan with Government of India's vision and has set a target to achieve Net-Zero (Scope 1 and Scope 2) status by 2040, while reducing our Scope 3 emission by 35% (from baseline year of 2020-2021) by 2040.

The company's Net-Zero strategy is based on 4 strategic pillars including Operational Decarbonization, Energy transition, Carbon Capture and Utilisation (CCUS) and Offsetting backed by a robust Governance structure.

GAIL is committed to install 1 GW of clean energy (including solar, wind, compressed biogas, ethanol, and green hydrogen) by 2025 and committed up-to INR 6000 crore. Further GAIL is targeting to augment its capacity to 3 GW of clean energy by 2030.

GAIL employees from all divisions share the following vision for combating climate change, which aids us in working together and strategically to achieve sustainability and Net-Zero:

- To ensure that the public has more access to affordable, reliable, and contemporary energy services with a low carbon footprint by accelerating the cost-effective provision of clean energy, renewable energy, and a Net-Zero business plan. Exploring potential of decentralized renewable energy incorporation, alternative fuels such as Compressed Biogas (CBG), and innovative technology to reduce emission by applying scientific rationale and testing.
- Enable and promote cooperation and partnership towards the implementation of Goal 7 by transitioning to Net-Zero CO_2 emissions by mid-century so as to meet the goals of the Paris Agreement including by introducing carbon pricing. A study on Carbon Pricing is expected to be published in FY 23.
- Increase awareness, capacity, and knowledge sharing, while also strengthening the ability of the supply chain of the company to take stronger action against climate change.

Methane is one of the potent GHG gas. To reduce GAIL's methane emissions, the company has taken various initiatives like installing, Flare Gas Recovery units (FGRU), increasing natural gas flaring rather than direct venting where possible and implementation of leak detection systems.

Photo Credit: Adobe Stock

GAS AUTHORITY OF INDIA LIMITED (GAIL)

STRATEGIC TRANSITION INITIATIVES

Renewable Energy (Wind / Solar)

GAIL has a total renewable energy portfolio of 134 MW with wind plants in Gujarat (19 MW), Karnataka (38 MW) and Tamil Nadu (61 MW) accounting for 118 MW. The remaining 16 MW comes from current solar plants at Rajasthan (5MW) & UP (5.8 MW), and from new installations at MP (2 MW) and 70+ locations (3.2 MW) currently under implementation.

The future for GAIL involves establishing renewable energy sources (including hybrid) for captive consumption, with cooperation with state governments or participating in Greenfield project tenders.

Biofuels

GAIL has plans to establish two 500 KLPD capacity 1G ethanol production plants in partnership mode at Rajasthan. Additionally, a joint venture has been setup with Gujarat Alkalis and Chemicals Ltd (GACL) for the establishment of a 500 KLPD plant in Gujarat based on corn.

237 LOIs for production of compressed biogas have been issued, with a capacity of 1184 TPD. CBG plant is being setup in Ranchi with an investment of 25 Cr which has a capacity of 5 TPD, with feedstock of 150 TPD of organic MSW and 15 TPD of cow-dung. Setting of CBG plant in other cities is being explored.

Carbon Capture, Utilization & Storage (CCUS)

GAIL have identified CCUS as one of the strategic pillars for its Net-Zero journey and is in process of identifying implementable CCUS technologies. GAIL has taken a keen interest in low carbon technologies & processes for valorization of CO_2 to valuable chemicals/ Fixing of CO_2. For this purpose, GAIL's R&D department has collaborated with eminent institutions of India, for undertaking feasibility study and technology development of process like:

- CO_2 to Methanol & DME (Dimethyl ether)- in collaboration with IIT-Delhi.
- CO_2 to Polycarbonate Diol- in collaboration with IISER- Tirupati.
- CO_2 to Syngas- in collaboration with IIP Dehradun

In addition to above technologies, GAIL has also implemented a pilot project for fixing CO_2 (1TPD) using Microalgae in an Open Raceway Ponds at Pata petrochemical complex in association with Central Institute of Mining and Fuel Research (CIMFER), Dhanbad. Trial runs have been initiated with suitable microalgae strains in the open ponds.

GAS AUTHORITY OF INDIA LIMITED (GAIL)

STRATEGIC TRANSITION INITIATIVES

Green Hydrogen

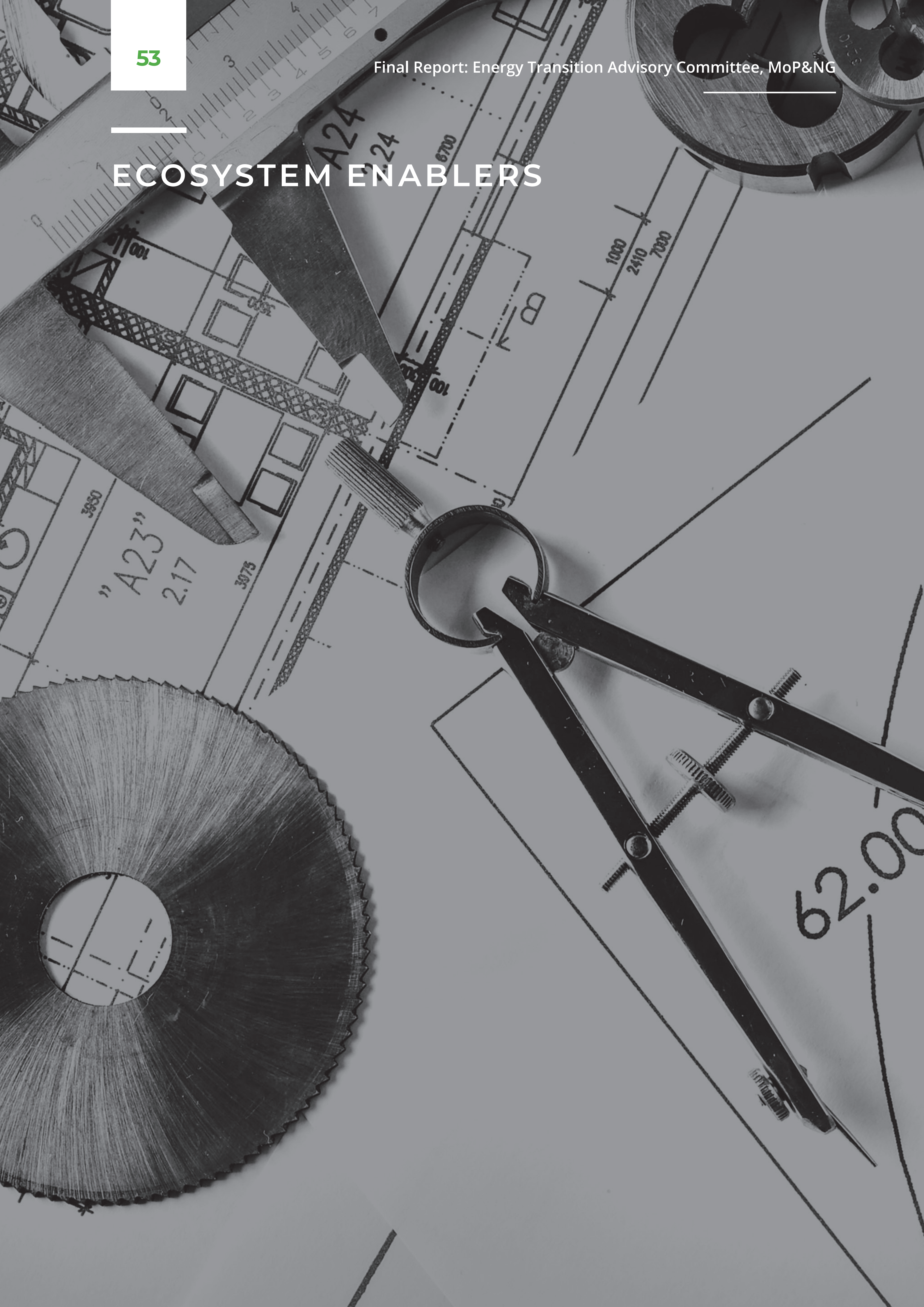
A 10 MW (4.3 TPD capacity) green hydrogen plant at Vijaipur is being planned with PEM electrolyzer technology. Hydrogen blending has begun at Indore CGD network, with PESO granted for blending of hydrogen from 1.1%- 2.0% for a trial period of 4 months. A study by EIL for blending of Green Hydrogen in CGD/ NG network is under progress to determine the maximum percentage of H_2 blending in the existing networks without any modification or with minor modifications. It is also studying how to make future new gas pipelines CGD networks ready for H_2 transportation through blending in natural gas.

Other Major Efforts

In addition to the above initiatives, GAIL is also undertaking following strategic initiatives for reducing its emissions:

- *Nature Based Offsetting:* GAIL has planted total 84,400 trees in FY 21-22 out of which 75800 trees were planted at their PATA plant. GAIL is in process of further augmenting this number, with the target of planning 1,50,000 more trees using "Miyawaki Forestry" technique in FY 22-23
- *Investing in Green startup:* GAIL has also setup an INR 100 crore corpus fund under its "Pankh" initiative majority of which has been utilized to invest in the green Start-ups and built a strong eco-system for green energy.
- GAIL is looking to incorporate several energy efficiency initiatives such as installing Flare Gas Recovery Unit (FGRU), Converting existing building into GreenCo certified green buildings. GAIL has also implemented energy management system at all our O&M locations with all our major installation being ISO 5001 Energy Management System certifies.

ECOSYSTEM ENABLERS



ENGINEERS INDIA LIMITED (EIL)

EIL is a critical partner for technology, innovation and energy solutions in the journey of energy transition for the energy industries. EIL specializes in design, development and implementation of process technologies both in the conventional and non-conventional energy segments. EIL holds a track record of achieving more than 60% indigenization of process technologies and 100% of engineering for the process industries. EIL has developed the technologies both in house and in collaboration with industries and academia alike such as IOCL, BPCL, CSIR (IIP, NCL, CSIO) and DBT-ICT. EIL has also forayed into implementation of biorefinery and other Green Energy sectors.

BASELINE

~8.0 $TMTCO_2E$

NET OPERATIONAL EMISSION (FY 2021-22)

TARGET

0.0 $MMTCO_2E$

NET OPERATIONAL EMISSION (2035)

ROADMAP TO NET ZERO

EIL estimated ~8,000 TPA of CO_2 emissions from its business operations inclusive of Scope 1, Scope 2, and Scope 3 emissions in FY22, out of which Scope 2 emissions (due to grid electricity consumption) constitute around 85%.

EIL has declared to become a Net Zero corporate by the year 2035 and formed a team to assess and implement relevant technological interventions in two phases to achieve this target (Exhibit 3.7).

Exhibit-3.7: Inventions planned by EIL to achieve net zero

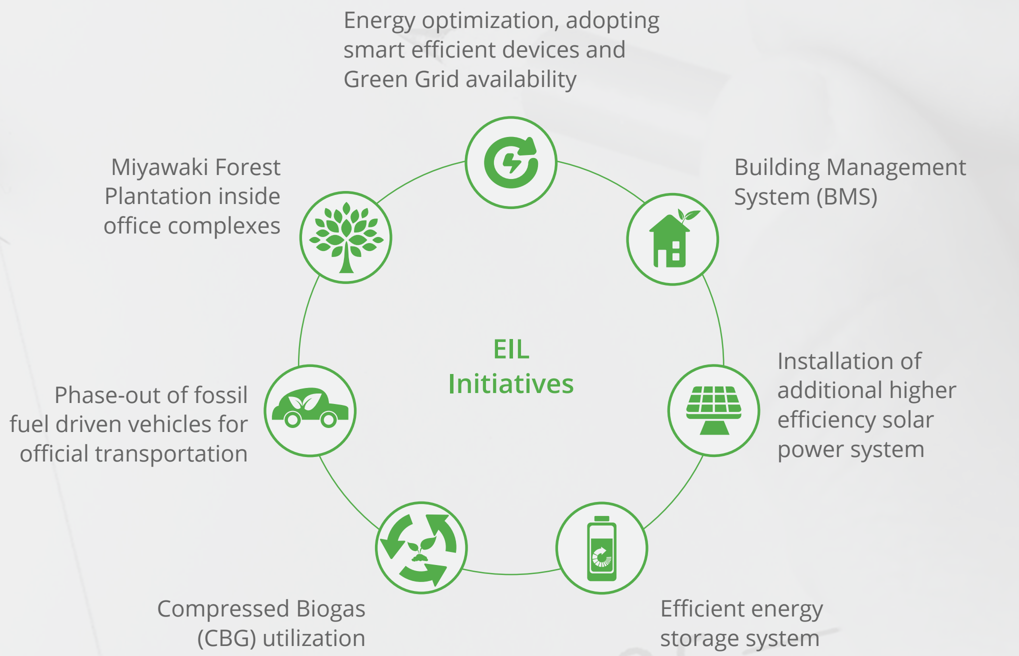


Photo Credit: Adobe Stock

ENGINEERS INDIA LIMITED (EIL)

STRATEGIC TRANSITION INITIATIVES

Energy Efficient Infrastructure

EIL is implementing important projects pertinent to energy efficient buildings. For instance, Leh Airport project is being built as a carbon-neutral airport and the IIM Nagpur campus, recently inaugurated by Hon'ble President of India, is a GRIHA 5 Star rated campus where EIL has provided its services as PMC. EIL is also developing its capabilities in sensor based technological solutions, with applications in Building Energy Management, in collaboration with CSIR-CSIO.

Biofuels

EIL's expertise in this area can be gauged by India's first 2G ethanol plant being set up by ABRPL (a JV of NRL, Fortum and Chempolis OY, Finland). The project is being implemented by EIL based on the technology supplied by Chempolis OY. This is one of the first that EIL has done so far in its more than five & half decades' long journey of providing services and building nation's energy infrastructure. EIL has also collaborated with IIP for Bio-ATF project towards decarbonizing the aviation sector.

Green Hydrogen

EIL has recently been involved by its esteemed clients in the following assignments that are essential to take a leap forward towards fulfilling India's aspiration for Green Hydrogen:

- Providing services for LEPC selection, Feasibility study & Basic design of OSBL facilities for Green Hydrogen Electrolyser and associated systems at BORL, Bina.
- Hiring of PMC Services for setting up 4.3 TPD Electrolyser at GAIL, Vijaipur
- Conceptual study for setting up Green Hydrogen facility in Dholera Special Investment Region, Gujarat.
- Study of Hydrogen blending in NG pipeline and CGD network, GAIL
- Feasibility study for hydrogen pipeline from Khavda to Mundra, ADANI Group

Carbon Capture, Utilization & Storage (CCUS)

EIL is involved in collaborative research with both academia and industry partners for effectively utilizing the carbon captured from point sources and has patented a solvent-based technology to capture the CO_2 generated from industry. The company is assisting industries in assessing CO_2 footprint from their business processes, systems, and infrastructure facilities. In this regard, EIL shall provide its services to develop a web-based platform to estimate the CO_2 emission from industrial set ups.

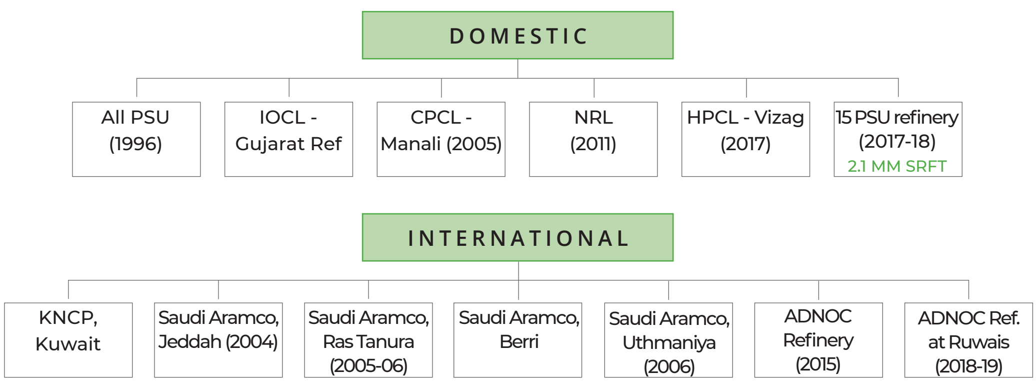
ENGINEERS INDIA LIMITED (EIL)

Digital Interventions towards Industrial Automation

EIL has developed IIoT based software solutions for optimizing the existing assets, suggesting the operating strategies for the heat and power networks, and increasing the efficiency of the furnaces, thereby transforming plant operations into interactive / real-time digital platforms. EIL is also involved in the implementation of sensor- based solutions for the Building Management System and Earthquake Warning System for key infrastructure projects in India.

EIL has assisted the industry in achieving Energy Optimization through a systematic approach and suggested short, medium, and long- term interventions to realize the potential energy savings (Exhibit-3.8).

Exhibit-3.8: EIL's experience in Energy Studies



Moving towards cleaner energy forms for the mitigation of climate change is no more a choice but a mandate for humankind to secure a sustainable future. EIL understands that a systematic, holistic approach by the stakeholders, including policymakers across the globe, is key to addressing the challenges associated with energy transition. This starts with uniform assessment and reporting of emission data on a common platform, followed by the deployment of innovative technological solutions. Technological solutions need to be not only effective but also economically viable for wider scale deployment.

Energy transition opens up immense opportunities for EIL to innovate and expand to provide total energy solutions to the industry. EIL has already forayed into diverse areas such as energy efficient infrastructure, alternative energy, green hydrogen etc. and building its capabilities to assist the industry in its energy transition journey. In this regard, EIL is committed to providing its services to develop a web-based platform to estimate CO_2 emissions across the carbon intensive industrial sectors. This platform would enable assessing emission data to bring uniformity such that the baseline and components related carbon footprint can be compiled on a common platform. This would, thus, help industry leaders in judiciously planning their futuristic investments and setting up targets for phase wise carbon footprint reduction towards net zero.

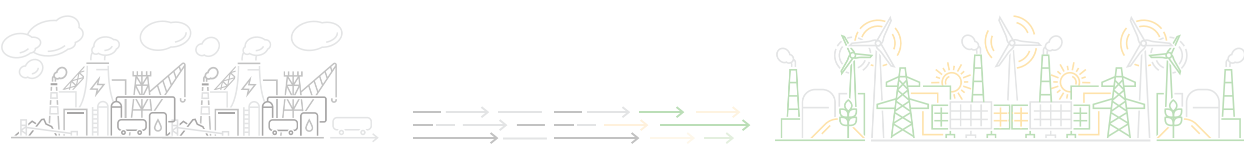
KEY RECOMMENDATIONS

Based on the interactions with and presentations made by different oil sector entities in the public and private sectors, it was apparent that they were adequately aware of the developments around energy transition, locally and globally – including COP trends and their business impact over short, medium, and long term. The following steps can help improve preparedness and enable these entities to face the emerging realities and benefit from them:

- **Formalize organization setup to tackle energy transition:** Establish a standardized structure for a cross-functional group dealing with the entire gamut of issues relating to ESG – carbon footprint measurement, carbon trading, environmental scanning, downside risk mitigation, identification of new business opportunities and fund-raising capabilities.
- **Integrate ESG into corporate reviews:** Channelize learnings from accurately measured scope 1 & scope 2 emissions, using globally accepted protocols like Science Based Targets, to orient corporate strategy towards identifying challenges and further mitigation opportunities in a timely manner. The sectoral entities deriving their revenue predominantly from fossil fuels need to also develop the capability to measure and manage scope 3 emissions, both upstream and downstream and participate in local and global efforts to mitigate overall carbon footprint across the value chain.
- **Register criticality of ESG goals & compliances across the organization:** Include ESG related issues, with a focus on energy transition, carbon footprint and ESG compliances, as a formal training module for all executives. To start with, it could be made available to all manager in mid-level and above. The organizations also need to recognize the fast evolving reporting requirements and devise an effective & comprehensive strategy to communicate / comply with the requirements of Integrated Reporting.
- **Expand Organizational capabilities:** The sector entities could consider developing supporting capabilities to manage emerging challenges & requirements. The organizations could develop these capabilities in-house or avail the expertise of external entities, including EIL, which has a history of extending consultancy services.

Exhibit-3.9: Main areas to expand Organizational capabilities

1. Accurate measurement & certification of carbon footprint along with its mitigation
2. Acting as or supporting the development of a Carbon Registry
3. Understanding and measurement of input and output side Scope 3 emissions
4. Development of carbon markets in India to enable funding through carbon trading
5. Enabling access to international financing for niche transition technology areas
6. Capitalizing on the knowledge and capabilities developed during the energy transition journey, identify value accretive business opportunities and benefit from them
7. The companies need to have a pro-active approach and remain ahead of the curve to capitalize on huge business opportunities that arise in the wake of global transition journey.



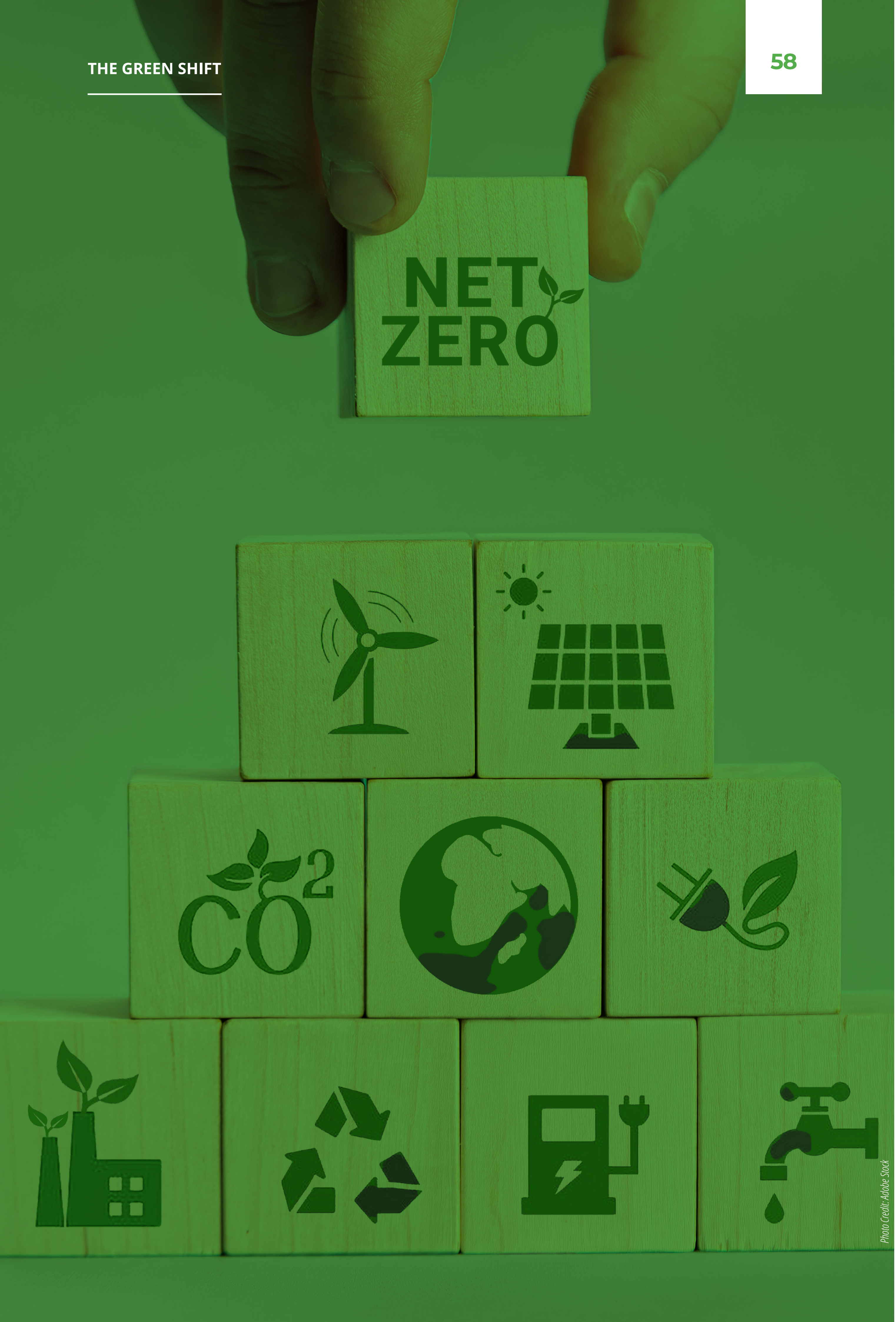


Photo Credit: Adobe Stock

Chapter 4

BIOFUEL OPPORTUNITIES IN INDIA

In this section

GLOBAL BIOFUELS PERSPECTIVE

Photo Credit: Adobe Stock

INTRODUCTION

Biofuels involve the direct conversion of biomass into liquid fuels, which can be blended with existing automotive fuels. Ethanol and biodiesel are the two main transport biofuels. These fuels can be produced from a variety of biomass. First generation (1G) biofuels are usually made from edible feedstock like sugarcane, beets, food grains etc. 2G fuels are produced from lignocellulosic biomass obtained from energy crops or waste biomass, such as agricultural and forest residue. Recently, biodiesel production from algal biomass has also evolved as an option, sometimes referred to as third generation (3G) biofuel. Algae can be used for the production of all types of biofuels, such as biodiesel, gasoline, butanol, propanol, and ethanol, with a high yield, approximately 10 times higher than 2G biofuel. Fourth generation biofuels (4G) are the amalgamation of genomically prepared microorganisms and genetically engineered feedstock. Cyanobacteria are engineered to increase the oil yield and are used to efficiently produce bioenergy. These feedstocks can be grown in nonarable land. Bioengineering principles are implemented to modify algal metabolism properties to enhance the oil content in the cells.

Moreover, the increased oil yield also helps in CO_2 mitigation. Hence, the net effect of CO_2 is negligible on the environment. Research in this field is emerging, and various methods have been proposed to provide a sustainable solution for biofuel production.

GLOBAL OUTLOOK

The international biofuel sector is strongly influenced by national policies that have three primary goals: farmer support, reduced GHG emissions, and increased energy independence. In the global transport fuel demand, the share of biofuels remains minimal, accounting for ~3%. Looking at the huge potential of biofuels as an alternative energy source, many countries have implemented dedicated biofuel plans with time bound blending mandates, incentivizing the setting up of distilleries and encouraging the production of energy crops to improve the situation. Biofuel demand in 2021 reached 155,400 Mn Liters, returning to near 2019 levels. Demand rose by 8,700 Mn Liters year on year.

The United States leads global biofuel growth, with demand expected to increase by 6% in 2022 compared to 2021 despite a downward revision in January. The recovery in gasoline and diesel use to pre-Covid levels, California's Low Carbon Fuel Standards, implementation of Renewable Fuel Standards and the Federal Biodiesel Blenders' Tax Credits, will all combine to drive this expansion.

In Brazil, a 1% growth in biofuel demand is forecasted in 2022 relative to 2021. Ethanol use is expected to expand slightly, despite weaker gasoline demand over time. As per the current outlook, ethanol prices are expected to remain more attractive than gasoline, which should lead to a higher blending share.

Europe's biofuel demand is expected to expand by 6% or 1,600 Mn Liters in 2022 relative to 2021. Growth is supported by more robust state level policies and rising gasoline and diesel demand recovering from Covid lows, albeit slower than forecasted earlier in the year. The ongoing geopolitical situation has created an unprecedented energy crisis for Europe, which may serve as a critical tailwind to prompt a significantly higher build up in Europe's bio-energy solutions.

In the Asia Pacific region, biofuel demand is expected to grow at 9% in 2022 and 12% in 2023 due to robust gasoline and diesel growth, supportive government policies in India and higher biodiesel blending requirements in Indonesia. India continues to raise ethanol blending mandate, reporting a 10% blending rate for ethanol in gasoline in May 2022. China contributes little to demand growth since there is no visibility on new support policies. China's 14th Five-Year Plan provided little insight on its biofuel plans other than reiterating its intent to "vigorously support advanced biofuels". Table-4.1 highlights the production share ranking and major feedstock utilized for ethanol and biodiesel respectively of major producers.

Table-4.1: Biofuel Production Share Ranking & Major Feedstock

	Production Ranking		Major Feedstock	
	Ethanol	Biodiesel	Ethanol	Biodiesel
USA	1 (48.2%)	2 (18.1%)	Maize	Soybean oil, UCO
EU	4 (4.8%)	1 (32.3%)	Sugar Beet/ Wheat/ Maize	Rapeseed Oil / Palm Oil / UCO
Brazil	2 (26.7%)	4 (12.2%)	Sugarcane / Maize	Soybean oil
China	3 (8.3%)	9 (2.3%)	Maize / Cassava	UCO
India	5 (2.3%)	15 (0.5%)	Molasses	UCO

Source: OECD-FAO Agricultural Outlook 2021-2030

World prices for biofuels are closely linked to developments in feedstock prices (which are mostly declining in inflation adjusted real terms), crude oil prices (which have remained constant in real terms), distribution costs and biofuel policies. International biofuel prices may increase in nominal terms but remain largely unchanged in real terms.

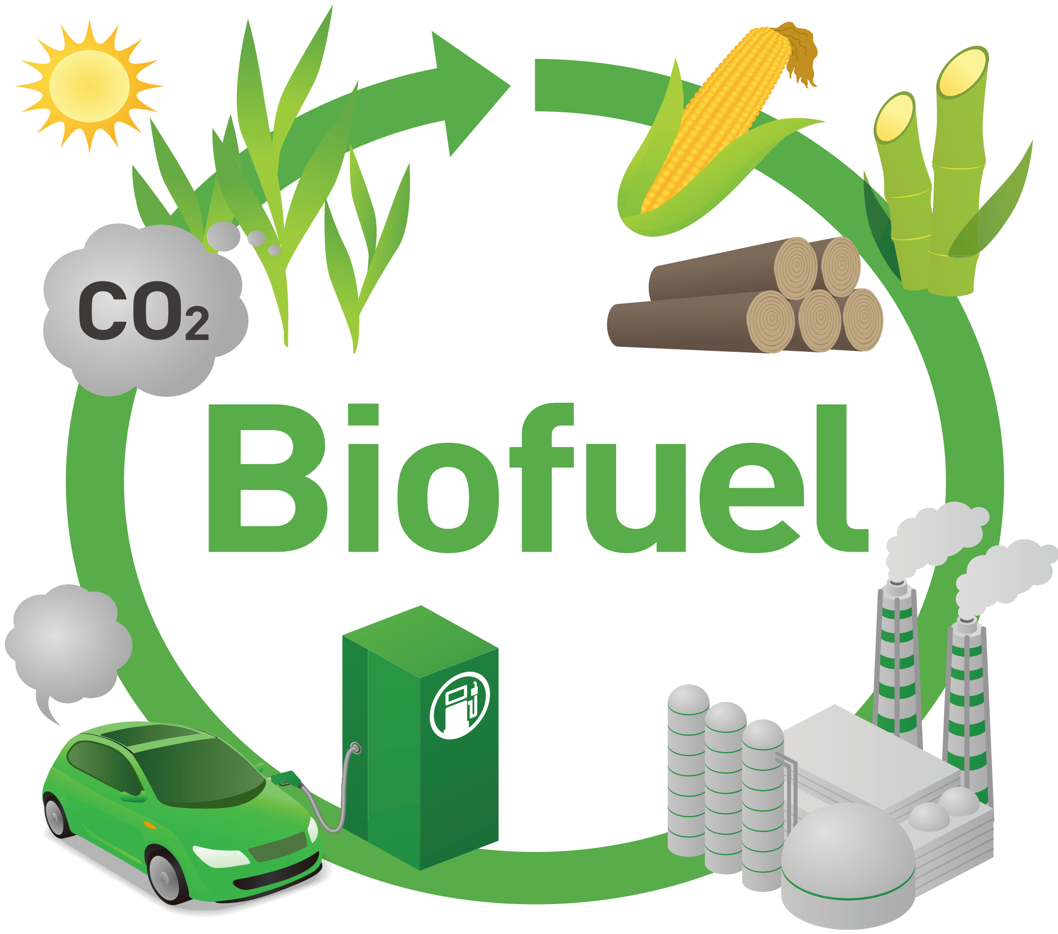
Based on the analysis of the Organization for Economic Co-operation and Development (OECD), globally nominal biodiesel prices are projected to increase at a slower pace (1.1% p.a.) than ethanol prices (1.8% p.a.) influenced by developments in the vegetable oil markets. Expressed in real terms, biodiesel prices are projected to decrease after 2024 and ethanol prices to resume a decreasing trend after 2026. Nominal ethanol prices will perform more strongly than biodiesel primarily because ethanol prices are currently at historic lows, and the recovery expected in the early years of the projection period 2021-2030 will start from this low base. It should be noted that due to policies that include fiscal benefits or support prices, international and domestic biofuel prices often diverge, and the trend of divergence is expected to continue going forward.

BIOETHANOL

INTRODUCTION

Ethanol production primarily involves distilling carbohydrates from sugarcane and beet or distilling starch from food grains such as maize, paddy, wheat, and potatoes through fermentation. Second generation fuels are produced from ligno-cellulosic biomass which is obtained from energy crops or waste biomass, such as agricultural and forest residue. Algae can lead to the production of all types of biofuels such as biodiesel, gasoline, butanol, propanol, and ethanol with high yields, approximately 10 times higher than the second-generation biofuel. Fourth-generation biofuels are the amalgamation of genomically prepared microorganisms and genetically engineered feedstock. The research into this field is emerging, and various methods have been proposed to provide a sustainable solution for biofuels production.

Exhibit-4.1: The Biofuel Value Chain



OUTLOOK

Ethanol is likely to be consumed more and more in the country where it is produced. Global ethanol trade is projected to remain a low share of global production, decreasing from 9% over the base period of 2021 to 8% by 2030. Due to weak production, US ethanol exports could also decrease during the outlook period. Brazilian ethanol exports are projected to increase by 0.1% p.a. over the outlook period through 2030, given that Brazil's ethanol industry will mostly fill sustained domestic demand.

INDIAN BIO-ETHANOL MARKET

Regulatory History

To boost the agriculture sector, reduce dependence on energy imports and harness the full potential of domestic sources, the Government of India launched pilot projects in 2001 wherein 5% ethanol blended petrol was to be supplied to retail outlets. Apart from field trials, R&D studies were also simultaneously conducted. The success of these field trials and studies paved the way for Ethanol Blended Petrol (EBP) in India. The Government of India, vide its resolution dated 3rd September 2002, decided to launch the sale of 5% EBP in nine States and four Union Territories (UTs) with effect from January 2003.

Thus, the Ethanol Blending Program in 2003 was the first significant policy step related to liquid biofuels. The Biofuel Policy, implemented in 2009, was more ambitious, mandating a 20% blending rate for ethanol and biodiesel by 2017. The 2009 policy also moved beyond molasses based ethanol production to the direct use of sugarcane juice. Despite these measures, ethanol production remained low in the ensuing years. Issues in the sugarcane supply chain prevented production, and oil marketing companies could not get bids for most of the quantity offered for purchase. This prompted a slew of measures in the next few years, including reintroducing administered minimum support price (MSP) and opening up alternate ethanol production routes.

By 2018, blending rates reached around 4%, followed by a faster uptake in the subsequent years. As of 2021, the Government of India reported a blending rate of 8.1%. From Aug 2021 to Jan 2022, Expression of Interest (EOI) for signing Long Term Offtake Agreements (LTOA) with Dedicated Ethanol Plants for ethanol supply saw OMCs sign 131 LTOAs. India achieved the targeted 10% ethanol blending in May 2022 (Table 4.2), much ahead of the target date of Nov 2022 and has gone on to prepone the timeline by 5 years to 2025 for an ambitious blending target of 20%.

Table-4.2: Trend in ethanol blending in India

Ethanol Supply Year	Quantity Supplied (Cr. Liters)	Blending Percentage for PSUs (%)
2012-13	15.4	0.67
2013-14	38.0	1.53
2014-15	67.4	2.33
2015-16	111.4	3.51
2016-17	66.5	2.07
2017-18	150.5	4.22
2018-19	188.6	5.00
2019-20	173.0	5.00
2020-21	302.3	8.10
2021-22	433.6	10.02

Source: OMC data

Bio-ethanol Demand in India

As witnessed in the case of global ethanol demand, even in India, demand for ethanol as a fuel will be primarily driven by blending mandates, widespread availability of fuel and compatible vehicles up to limited blending percentages, and fulfilment of other infrastructural requirements.

As of July 11th, 2022, the vehicle population in the country was estimated at around 22 Cr two and three wheelers and about 5.4 Cr four-wheelers (Vahan data). Two and three wheelers account for 74%, and passenger cars around 19% of the total vehicle population on the road. Two and three wheelers consume 2/3rd of the gasoline by volume, while four wheelers consume the balance 1/3rd by volume. The growth rate of vehicles in this segment is pegged at around 8-10% per annum.

As indicated in the roadmap in the NITI Aayog report released in June 2021, the projected requirement of ethanol based on petrol (gasoline) consumption and estimated average ethanol blending targets for the period ESY 2020-21 to ESY 2025-26 are calculated below in Table-4.3.

Table-4.3: Ethanol demand projection

Ethanol Supply Year	Projected Petrol Sale (MMT)	Projected Petrol Sale (Cr. liters)	Blending (in %)	Ethanol required for blending in Petrol (Cr. liters)
A	B	B1=B X 141.1	C	D=B1 x C%
2019-20	24.1 (Actual)	3413 (Actual)	5	173
2020-21	27.7	3908	8.5	332
2021-22	31	4374	10	437
2022-23	32	4515	12	542
2023-24	33	4656	15	698
2024-25	35	4939	20	988
2025-26	36	5080	20	1016

Source: Niti Aayog Report - Roadmap for Ethanol Blending in India 2020-25

Feedstock for Production

The Department of Food and Public Distribution (DFPD) is the nodal department for promoting fuel grade ethanol producing distilleries in the country. The Government has allowed ethanol production and procurement of sugarcane based raw materials, viz. C & B heavy molasses, sugarcane juice and sugar / sugar syrup, surplus rice from Food Corporation of India (FCI) and maize. The conversion efficiency by raw materials is tabulated in Table-4.4 below:

Table-4.4: Feedstock for Production

Feedstock	Cost / MT of the feedstock (Rs.)	Quantity of ethanol per MT of feedstock	Ex-mill Ethanol Price (Rs./liter)
Sugarcane juice / Sugar / Sugar syrup	2850 (Price of sugarcane at 10% sugar recovery)	70 liter per ton of sugarcane	62.65
B Molasses	13,500	300 liters	57.61
C Molasses	7,123	225 liters	45.69
Damaged Food Grains (Broken Rice)	16,000	400 liters	51.55
Rice available with FCI	20,000	450 liters	56.87
Maize	15,000	380 liters	51.55

Source: Niti Aayog Report - Roadmap for Ethanol Blending in India 2020-25

Sugarcane

Sugar based ethanol production uses molasses, a byproduct of the sugar-making process, almost exclusively. A lifecycle analysis done as part of a 2015 study by Soam et al. found that without allocation among co-products, lifecycle emissions for molasses based ethanol were 8,736 kg CO_2 eq./ ton of ethanol, compared to 512 kg CO_2 eq./ton of ethanol when energy-use was apportioned. On the land use change required for increased sugarcane production, taking a concept from Ju Young Lee et al., it is estimated that the goal of producing 6.78 Bn Litres of ethanol from sugarcane will require an additional 6.26 Mn hectares under sugarcane by 2025. The other sugarcane pathway involves using sugarcane juice directly, possibly reducing the need for land-use change. However, sugarcane cultivation is water intensive and depends heavily on consistent rainfall patterns. ***Meeting the ambitious goal of producing ethanol from sugarcane necessarily needs an environmentally sustainable agriculture production system.***

Rice

To meet the 2025 ethanol production target of the new roadmap, an estimated 17 Mn tons of food grains will be needed, a staggering increase from the 78,000 tons of Food Corporation of India (FCI) rice allocated in FY 2020-21. Due to excess procurement during the pandemic, the current rice stocks are much higher than the average stocks in the last few years. The stock also varies seasonally, with a significant uptick following the Rabi cropping season. ***Thus, a steady and sustained supply of surplus rice needs to be ensured in long run.***

Maize

Since using rice for ethanol poses significant risks to food security, rice can be seen as a temporary source. Thus, food grain based ethanol production will depend on maize in the long run. In India, maize production in FY 2020-21 stood at 24.51 tons, with stable production over the last five years. Presently, most of the maize is utilized for poultry feed (47%); the rest is used for livestock feed (13%), starch (14%), and exports (6%). As per estimates from the Indian Institute of Maize Research (IIMR), the average yield for maize in India is 2.8 tons/ha. and 4.4 tons/ha. in the Kharif and Rabi seasons, respectively. This is less than half the US average yield of 10.4 tons/ha. and lower than that of most other maize producing countries. Considering an ethanol yield of 380Liters/ ton, meeting the food grain requirement for ethanol production from maize will require an additional 4.82 Mn ha. of land, more than half of the present 9.42 ha. under maize cultivation. ***Thus, a maize dependent pathway will require significant land use change, and dynamically calibrated marketing policies to avoid a shortage of supply in the domestic market.***

Summary

Thus, India's present approach to biofuel production presents the following key challenges for feedstocks from a lifecycle perspective which needs to be accordingly addressed:

- The low yield for sugarcane and maize in India will require land use change, which necessitates the exploration of new production pathways.
- The agricultural sector receives subsidies for inputs and power in addition to MSP, leading to unsustainable water use and fertilizers. Thus it is necessary to explore less water intensive agriculture methodologies, more so for sugarcane cultivation and sustained long term ESG compliances.

- Land revival programs are inhibited by the lack of a robust mechanism for classifying wastelands and complicated land ownership patterns that need to be investigated.
- Using competing agricultural feedstocks can create conflict between different agrarian groups, which may need to be balanced.
- Promoting 1G biofuels may lead to technology lock ins and delay switching to 2G feedstocks. A reasonable level of uniformity in incentives for sugarcane and maize production and other feedstocks will be desirable for seamless bioethanol expansion.
- There is a need for sustainability standards to safeguard rural development. This may include supporting local communities, providing jobs, ensuring human rights protection, improving air and water quality, and avoiding deforestation.
- Rain and other weather related issues are significant factors impacting agriculture based feedstock availability and sustained supply. In a year of insufficient rain or other weather related disturbances, it is possible that the feedstock supply could be hindered. Therefore, measures such as calibrated control on exports, good stock build up and price assurance may be used as mitigatory measures under such circumstances.

Second-Generation Biofuels: From promise to reality

The advancements in 2G bioethanol produced from lignocellulosic biomass, such as crop residues, woody crops or energy grasses, are gaining momentum. Though they still represent less than 3% of total bioethanol production globally, the GHG reduction potential is higher than for 1G bioethanol. The environmental impacts of bioethanol production are dependent on feedstock availability and conversion technology. The biochemical conversion route must overcome technological and economic challenges such as pre-treatment, fermentation, hydrolysis and separation.

India has four operational advanced biofuel plants, including a pilot and a demonstration plant, with a cumulative annual production capacity of 1.75 Mn Liters of cellulosic ethanol. Actual production is a mere fraction of this figure. There are several advanced biofuel plants in development, but they are far from reaching commercialization as of now.

Under the PM JIVAN scheme, 12 commercial plants and 10 demonstration plants of 2G biorefineries are planned to be set up in areas with sufficient biomass availability so that ethanol is available for blending throughout the country. Already Rs. 1,969.50 Cr has been earmarked for this scheme. These plants can use feedstocks such as rice and wheat straw, corn cobs and stover, bagasse, bamboo, woody biomass, etc. Currently, three major commercial 2G plants are in the process of being commissioned, including BPCL Bargarh (30 Mn Liters), HPCL Bhatinda (30 Mn Liters) and Numaligarh Refinery Limited (60 Mn Liters). The IOCL Panipat plant of 30 Mn Liters was dedicated to the nation by the Hon'ble Prime Minister of India on 10th August 2022, World Biofuels Day. The issue of pricing, market creation of byproducts, availability and logistics of feedstocks are being addressed further.

The Technology Information, Forecasting and Assessment Council's (TIFAC) 2018 report estimates India's total dry biomass generation at approximately 683 MMT across 11 crops suitable for biofuel production. Based on the above study by TIFAC, it was found that sugarcane, rice, and wheat are the most grown crops in India, accounting for over 91% of the production of crops. Rice straw, rice husk, wheat straw, sugarcane tops and bagasse are the main crop residues generated in India. They account for almost 80% of the residue generated by the crops. Assessing the sustained availability of feedstock over time is critical, considering that in certain situations, especially in periods of reduced supply, 1G feedstock affect ethanol supply, resulting in variations in price and availability of animal feedstock. TIFAC has recently undertaken a study to assess the projected availability of agricultural residue for ethanol production. Based on a preliminary assessment, it is estimated that through major crops by FY 2021-22, around 200-250 MMT of surplus agriculture residue may be available for producing bioethanol.

Currently, the available commercial technologies can yield 250 Liters of ethanol from one ton of agriculture residue. The overall shortfall of 5.9 Bn Liters could be met effectively if merely 12% of the surplus biomass (200 MMT = ~ 50 Bn Liters) is utilized for producing bioethanol. However, with plans to go for 20% ethanol blending, it will require necessary modifications in the vehicle engine parts and progressively lean towards "flex-fuel" engines. The modified engine vehicles will enable the absorption of all the additional bioethanol, the availability of which is not foreseen to encounter any problem. In ramping up the collection of feedstocks from crop residues, establishing the necessary infrastructure for collecting, transporting, and handling large amounts of biomass would be a crucial step toward boosting biofuel use in India. This would allow the country to enter 2G biofuel production, given the fact that technical and cost barriers have been reduced to some extent.

Summary

- Consistent availability of feedstock from crop residues, and the establishment of necessary infrastructure for aggregation, logistics and handling of large amounts of biomass, all with the least carbon footprint, will be a step toward 2G ethanol production. The technical and cost barriers also need to be overcome.
- A framework would be required to assess the projected biomass residue and identify the potential of biofuel production and the associated number of prospective bio-refineries in a region/ state based on the current and projected availability of agricultural / biomass residues.
- There is a need to establish synergy among all the concerned Ministries to take the mission forward and make it easier for investors to acquire land, access geographical information of various producing areas, avail single window clearance for obtaining licenses, financing options, reasonable pricing with off-take guarantee etc.
- To ensure the sustained availability of feedstock for bio-energy projects, it is necessary that a mechanism for the preferential availability of crop residues for usages like CBG, bio-ethanol etc. is mandated.
- Technology for ethanol production from non-food feedstock should be promoted to tap this abundantly available resource without causing any trade-off.

Supply situation in India

To enhance ethanol production capacity in the country, the Government, in July 2018 and March 2019, notified two interest subvention schemes for molasses based distilleries. Under the aforesaid scheme of the Department of Food and Public Distribution (DFPD), interest subvention at the rate of 6% per annum or 50% of the rate of interest charged, whichever is lower on loan sanctioned, was borne by the Central Government for a period of 5 years. The DFPD approved 368 projects for setting up new distilleries and expansion of existing distilleries under the scheme. Thus far, 238 projects for a capacity enhancement of 583 Cr Liters with a loan amount of about Rs 16,000 Cr have been approved by the DFPD.

The Cabinet Committee on Economic Affairs (CCEA), in its meeting dated 30th December 2020, approved extending financial assistance for producing 1G ethanol from feedstocks such as cereals (rice, wheat, barley, corn & sorghum), sugarcane, sugar beet etc. The DFPD notified a modified interest subvention scheme on 14th January 2021 for setting up new and existing grain based distilleries to produce ethanol & production of ethanol from other 1G feedstocks. About 418 applications received for capacity addition of 1,670 Cr Liters have been recommended for approval in principle. It is expected that the capacity of molasses based distilleries will increase from the current levels of 426 Cr Liters to 730 and 760 Cr Liters by FY 2024-25 and FY 2025-26, respectively.

The Department of Financial Services (DFS) has impressed upon banks to expedite sanctioning and disbursal of loans. The concept of a Tripartite Agreement between mills/distilleries, banks, and OMCs has been introduced to help mills/ distilleries avail loans for ethanol projects. State Bank of India has also issued Standard Operating Procedures (SOP) to sanction and disburse loans to molasses based distilleries. Similar SOPs are also being issued for grain based distilleries by other banks. The DFPD has developed a web portal viz. http://sugarethanol.nic.in to review the progress of upcoming ethanol projects in real time. In the portal, project proponents can share the bottlenecks faced by them so that related ministries like DFS, MoEFCC, DFPD, MoPNG and state governments can sort out their problems by expediting requisite clearances and sanctioning and disbursal of loans.

About 988 Cr Litres would be required to achieve the 20% blending target by FY 2024-25, and the total requirement of alcohol, including other sectors, would be 1,288 Cr Litres. For FY 2025-26, ethanol requirements would be 1,016 Cr Litres to achieve 20% blending and the total requirement of alcohol, including other sectors, would be 1,350 Cr Litres.

Table-4.5: Ethanol Capacity Augmentation (20% blending by ESY 2025-26)

Ethanol Supply (in Cr. Lt.)	Molasses based	Grain based	Total
(A) From sugar sector	550	134	684
(B) From grain/ maize etc.	466	200	666
Total Supply	**1016**	**334**	**1350**

Ethanol Capacity Augmentation (in Cr. Lt.)	Molasses based	Grain based	Total
Existing ethanol / alcohol capacity	426 (231 distilleries)	258 (113 distilleries)	684
Capacity addition from sanctioned projects	93	0	93
New capacity to be added (already added for 370 Cr. litres by May '22)	241	482	723
Total Capacity required by Nov 2026 to reach 1350 Cr litres supply	**760**	**740**	**1500**

Source: Niti Aayog Report - Roadmap for Ethanol Blending in India 2020-25

Technology for Higher Ethanol Blend (>20%)

A project to study the suitability of using 20% ethanol gasoline blend (E20) for powering vehicles was undertaken by the Automotive Research Association of India (ARAI), Indian Institute of Petroleum (IIP) and IOCL during FY 2014-15, with funding from the Department of Heavy Industry (DHI). Material compatibility tests revealed that the metals and metal coatings had no issues with E20. Elastomers (NBR/PVC blend and Epichlorohydrin) had an inferior performance with E20 compared to neat gasoline. Plastic PA66 had a drop in tensile strength after use with E20. In vehicle level studies, fuel economy decreased by up to 6% (depending on the vehicle type) on average. The test vehicles passed startability and drivability tests under hot and cold conditions with E0 and E20 test fuels. In all the cases, no severe malfunction or stalling was observed at any stage of vehicle operation. No abnormal wear of engine components or deposits or deterioration of engine oils were observed after the on road mileage accumulation trials. Joint studies reported by the Massachusetts Institute of Technology and Honda R&D indicate that upto 20% improvement in relative efficiency can be achieved with E20 compared to regular gasoline when the engine is tuned correctly.

Flex Fuel Engine technology (FFE) is a well-accepted concept in Brazil, representing over 80% of the total number of new vehicles sold in the country. The Flex fuel vehicles used in Brazil operate with E27 or E100 Hydrous ethanol or any blend between these two. So, the selection and optimization of technology for the engine must be undertaken considering the availability of ethanol fuel. The cost of flex fuel vehicles (four wheelers) would be higher in the range of Rs 17,000 to Rs 25,000. The two-wheeled flex fuel vehicles would be costlier in the range of Rs 5,000 to Rs 12,000 compared to standard petrol vehicles (according to SIAM).

It is recommended in Niti Aayog's roadmap that E20 material compliant and E10 engine tuned vehicles may be rolled out across the country from April 2023. These vehicles can tolerate 10% to 20% of ethanol blended gasoline and give optimal performance with E10 fuel. Vehicles with E20 tuned engines will be rolled out nationwide from April 2025. These vehicles will run on E20 only and provide high performance.

An ambitious and calibrated transition towards an E20 regime will expectedly impact multiple stakeholders in the ecosystem in myriad ways. Higher reductions in CO emissions were observed with E20 fuel at almost 50% lower in two wheelers and 30% lower in four wheelers. Hydrocarbon emissions are reduced by 20% with ethanol blends compared to regular gasoline.

For consumers, while using E20 fuel, there will be a drop in fuel efficiency by nearly (a) 6-7% for four wheelers designed for E0 and calibrated for E10, (b) 3-4% for two wheelers designed for E0 and calibrated for E10 (c) 1-2% for four wheelers designed for E10 and calibrated for E20. However, with the modifications in engines (hardware and tuning), the loss in efficiency due to blended fuel can be reduced.

For vehicle manufacturers, engines and components need to be tested & calibrated with E20 as fuel. Vendors need to be developed to supply additional components compatible with E20. All the parts required can be made available in the country. Component manufacturers must ensure the availability of compatible piston rings, piston heads, seals, fuel pumps etc., in India.

KEY POLICY INTERVENTIONS

Supply / Feedstock related

- OMCs would be following the path laid down in the Niti Aayog Roadmap for Ethanol Blending 2020-25.
- Promote proliferation of nonfood feedstock: Promote technology for the production of ethanol from nonfood feedstock, called "Advanced Biofuels," including 2G and 3G (Industry off-gases, Municipal Solid Waste) to minimize trade-offs with the food production system. Governments to declare a mandate for a minimum quantity of ethanol to be procured from 2G/3G sources.
- *Encourage production from crops with a lower environmental burden:* Expand production from maize, sorghum and other low water consuming feedstock. Even energy cane prominently used in Brazil for 2G Ethanol can be adopted as a low water guzzling crop.
- *Establish an efficient supply chain for feedstock / ethanol movement:* Develop a supply chain policy framework (including for storage & distribution infrastructure) to optimize the movement of feedstock and ethanol from production to consumption points with the lowest carbon footprint.

Transportation through pipelines and rakes is to be encouraged to reduce logistical costs and carbon footprint. Strong synergies between the center, states and cooperative societies will be required. It will be important to work on regional planning. Excess ethanol capacity in states can be moved to adjoining states where there is a shortfall. Based on upcoming plants, a medium term picture of at least up to FY 2025 -26 can be worked out to arrive at a regional balance. CPSUs' upcoming project capacities to be considered for the calculation of the overall ethanol supply / demand position & commissioning dates of each CPSU plant may be ascertained.

- In states where there were nil or few responses in 1st EOI, OMC can go for ethanol offtake from vendors who wish to set up ethanol plants at this stage without a long term offtake guarantee. They can register for 5 years to get an assurance of offtake and may be encouraged to set up capacities.
- OMCs may discuss with ethanol manufacturers / ISMA for direct loading of rakes from distilleries where railway sidings already exist and supply to those states which are likely to remain in deficit even after 2025. Ethanol hubs or large storage can be developed in places where supplies can be aggregated and transported to deficit states.
- Promote investment in the North East: Attract investors to the North East of the county to avail of the Interest Subvention Scheme of DFPD and build adequate distillation capacity to avoid long distance transport of ethanol.
- As railways are going for 100% electrification in the coming 3 to 4 years, there will be a surplus of diesel storage tanks in Railway Consumer Depots (RCDs) across India. The same surplus tanks may be used by OMCs for ethanol storage..
- Micro plans for each depot would be prepared by the primary coordinators. This should indicate month-wise expected capacities for their respective depots from producers within 50 Km, beyond 50 Km and up to 100 Km and beyond 100 Km. The primary coordinators can then calculate storage requirements and monitor supplies as well as blending. They must also estimate the assured capacity and likely capacity from each supplier within these geographical ranges.
- *Establish feedstock pricing mechanism:* Design a feedstock pricing mechanism linked to bioethanol prices and the logistical distance at various collection points to avoid feedstock suppliers' (farmers') exploitation by the biofuel producers.
- Institutionalize certification systems for GHG savings: Utilize recognized certification systems such as the International Sustainability & Carbon Certification (ISCC) system for sustainability and GHG savings of all kinds of biomass, including feedstocks for bioenergy and biofuel production.
- Disincentivize export of feedstock sources: Mitigate the low feedstock situation by designing export prohibition mechanisms.

Associated Infrastructure

- *Storage for ethanol to be developed* at distilleries, OMC depots, and OMC rake loading locations. The cumulative storage for OMCs and ethanol distilleries should at least cover requirements for 45 days, i.e., storage of around 135 Cr. Ltrs. Distilleries that supply outside the state shall have higher storage capacity. Ethanol vendors must have at least 20 days of coverage.
- *Transition to E20 and beyond fuels:* OMCs must plan to dispense E20 and beyond by putting up required infrastructures at retail outlets so that flex fuel vehicles can purchase any blend over and above 20% and up to 100%. Base fuel should initially be kept at 20% and progressively increased to a higher blend depending upon the availability of ethanol year on year.

- *Enable speedy information support & government clearance:* Establish a system for single window clearances by DPIIT to accord quick approvals for new and expansion projects for ethanol production by Central and State agencies, including PESO. Facilitate ease for investors in land acquisition, geographical information of various producing areas, financing options etc., through cross ministry coordination.
- *Expedite establishment of a National Biofuel Fund:* Establish a fund reserve for providing financial incentives as indicated in the National Policy on Biofuels, like subsidies and grants for new and 2G feedstocks and associated conversion technologies. The possibility of aggregating the mitigated carbon footprint and using proceeds from carbon credits should be examined to reduce the cost of funds.
- *Simplify movement of goods:* Unrestricted movement of denatured ethanol meant for EBP should be allowed by all states.
- *Establish an enabling ecosystem to attract external investment:* The Government must actively generate investor interest to ensure the sufficient installation of new biorefineries. This includes accelerated clearances and expanding marketing through the support of alternative uses such as power generation & backup usage (such as for cooking or telecom towers).
- *Establish an alliance for collaboration & knowledge sharing:* Establish an International Biofuels Alliance, in line with the International Solar Alliance, to collaboratively learn and grow by facilitating access to technological innovations and creating a structured market. Since India holds the G20 presidency from December 2022 to November 2023, it would be apt to promote the International Biofuel Alliance at the G20 summit.

Vehicle Standards / Awareness

- *Promote the adoption of flex fuel vehicles:* Flex fuel vehicles should be encouraged and popularised for moving beyond E20. In India, E20 should be declared as the base fuel on similar lines as Brazil, where E27 is the base fuel. Dispensing of pure ethanol to be introduced on a large scale to fast track the adoption of flex fuel vehicles.
- *Popularise benefits of EBP in the masses*: Launch nationwide educational campaigns, led by concerned ministries in partnership with the industry, to educate the consumers about the benefits of EBP and enable the selection of appropriate fuel for their class of vehicles. This will help gain customer confidence and acceptance for E20 and higher blends.
- *Financially incentivize compliance with higher ethanol blends*: Provide tax benefits to vehicles compliant with higher ethanol blends. Promote adoption by setting the retail price of such fuels lower than normal petrol to compensate for the reduction in calorific value. Eventually, ethanol-blended / hybrid vehicles would help reduce the carbon footprint of vehicles and hence need to be supported through a policy.
- *Need for closer coordination with vehicle manufacturers* through policy and other enablers to ensure that vehicle production technology is also upgraded consistently with changing fuel rollout plans.

BIO DIESEL

INTRODUCTION

Rudolph Diesel developed biodiesel in 1890, wherein pure vegetable oils were used in diesel engines for agriculture when petroleum diesel was unavailable.

Modern biodiesel fuel is an outcome of research conducted in the 1930s in Belgium and made by converting vegetable oils into compounds called fatty acid methyl esters. Biodiesel is being used worldwide now due to its positive contribution to addressing global warming concerns.

The future of biodiesel lies in the world's ability to produce renewable feedstocks such as vegetable oils and fats to keep it cost competitive with petroleum fuels.

OUTLOOK

The world biodiesel market is estimated at approximately 43 Mn MT per year (2021), with the EU at 14 Mn MT (2018), the USA at 7.2 Mn MT (2018), and Brazil at 4.68 Mn MT (2018). The remaining markets comprise of Southeast Asia (i.e., for palm oil) and China (i.e. for soybean oil, palm oil and UCO or "gutter oil").

India produces only a minuscule portion of global volumes at 0.163 Mn MT per year, constituting only about 0.4% of the world market. Weather impacts on biofuel crops, growing corn and soybean demand in China and certain other markets, and higher shipping costs contribute to higher biofuel prices. These costs have increased by between 70% and 150% from the 2019 average and bio-diesel feedstock prices are more than prices for crude oil in most cases, increasing the spread between bio-diesel and fossil fuel costs.

INDIAN BIODIESEL MARKET

Regulatory History

The Ministry of Petroleum & Natural Gas proclaimed a biodiesel purchase policy effective from January 2006. According to the policy, oil marketing companies were to purchase biodiesel for Rs. 26.5 / Litre at 20 purchase centres in 12 states. Suppliers had to register with state level coordinators and meet the Bureau of Indian Standards (BIS) specifications. The oil companies, on their part, were to blend conventional diesel with biodiesel up to a maximum of 5 % at the purchase centres.

In September 2008, a "National Policy on Biofuels" was approved, and it was decided to set up a National Biofuel Coordination Committee. The National Policy on Biofuels reaffirms that biodiesel production will only be promoted based on non edible oil seeds on marginal lands. The focus was on indigenous biodiesel feedstock production. Importing oil from other crops (e.g., oil palms) was not permitted. Biodiesel plantations on community and government lands were encouraged, while plantation on fertile irrigated lands was not encouraged.

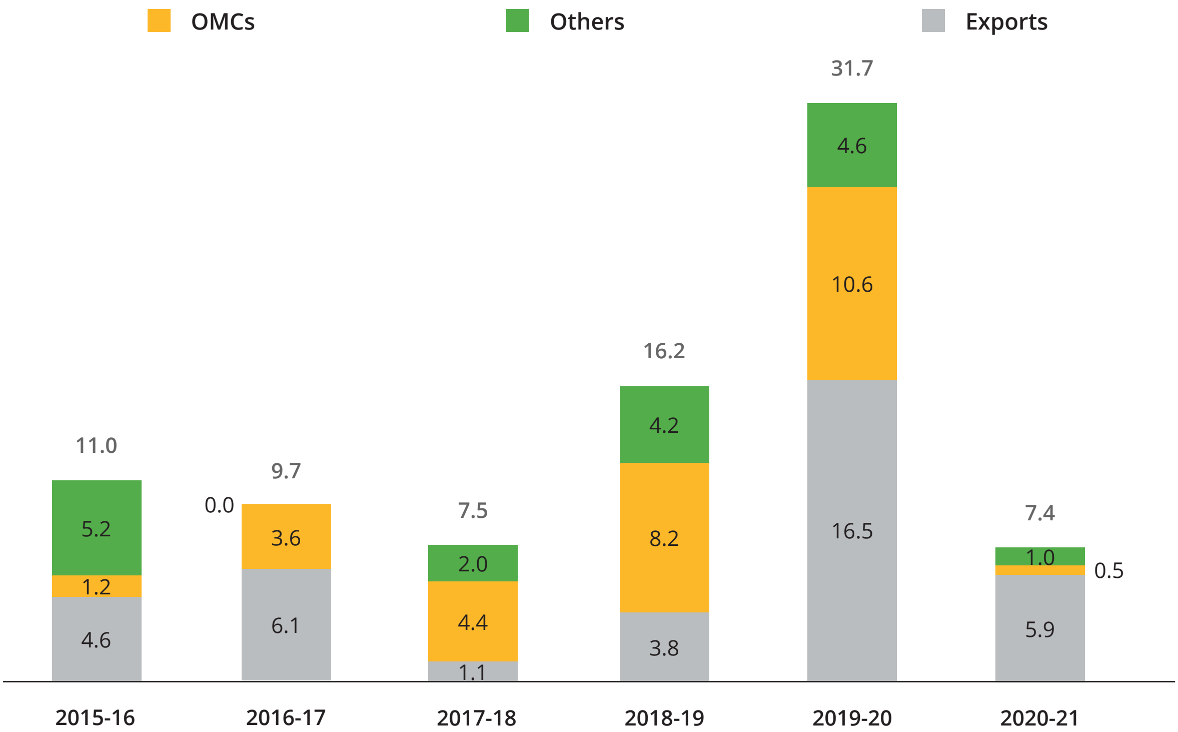
In the National Biofuels Policy 2018, India set a target of 5% biodiesel blending in diesel by 2030. The Policy encourages the setting up of supply chain mechanisms for biodiesel production from non edible oilseeds, UCO, and short gestation crops. With a thrust on Advanced Biofuels, the Policy includes a viability gap funding scheme for 2G ethanol bio refineries of Rs 5,000 Cr in 6 years in addition to additional tax incentives and a higher purchase price as compared to 1G biofuels.

Biodiesel Demand in India

Biodiesel is expected to play an important role for the oil & gas industry in promoting energy sustainability and security as India progresses toward a clean energy ecosystem.

The consumption of High Speed Diesel (HSD) in the country stands at 76.7 MMT/93.13 MKL in FY 2021-22 and is projected to be 96.2 MKL in 2022 by PPAC. At 5% blending, 481 Cr. Liters of biodiesel would be needed in 2023. The consumption of HSD is expected to be 16,900 Cr. Liters by 2030, thus, demand for biodiesel will grow to approximately 845 Cr. Liters by 2030.However, in FY 2019-20, the most successful year so far, only 10.5 Cr. Liters of biodiesel were procured by OMCs for blending. This constituted just 0.12% of HSD against the 5% target. There are more than 50 MSME units and five large bio-diesel units currently operating in India with a nameplate capacity of 150 Cr. Liters per annum. About 90% of biodiesel produced presently in India is from imported palm stearin, while the rest is from animal tallow, acid oil and UCO. The sale of biodiesel was highest in FY 2019-20, which declined due to the unavailability of raw materials during the pandemic (Exhibit-4.2).

Exhibit-4.2: Biodiesel Offtake (in Cr. litres)



Source: BCG Analysis

Biodiesel Production & Feedstock Potential

Biodiesel Production

Biodiesel can be obtained from any triglyceride feedstock like vegetable oils (fresh or used), animal fats, algae, and algal lipids. The literature contains hundreds of references to biodiesel production from various feedstocks.

Currently, however, the dominant feedstocks are soybean oil in the US, rapeseed oil in Europe, and palm oil in Southeast Asia. Animal fats (especially beef tallow) and UCO (also called yellow grease) represent significant niche markets for biodiesel in many locations. Other vegetable oils having a real or potential commercial interest as biodiesel feedstocks include camelina, canola, coconut, corn, jatropha, safflower, and sunflower. Presently, biodiesel is being produced in India primarily from imported palm stearin oil and animal tallow. As per a study on the biodiesel produced in FY 2019-20, 93% of biodiesel was generated from palm stearin, and an almost negligible amount of UCO was utilized for production (Table-4.6).

Table-4.6: Biodiesel Production in India (2018-19)

Feedstocks	Biodiesel Produced (Cr. litres)	Contribution (%)	Total availability of feedstock (MT)
Domestic RBD Palm Stearin*	9	93% of feedstock	2,00,000 MT
Imported RBD Palm Stearin*	6		Depends on international supply chain and availability
Animal Tallow** (Buffalo)	0.5	3.50%	1. 250,000 is available in India but is mostly exported, thus low availability 2. Import of Tallow is banned
Acid Oils***	0.4	2.50%	1. Current availability is 45,000 MT 2. Import uneconomical at most times
Used Cooking Oil***	0.1	1%	1. Small quantity available for Biodiesel 2. Import is banned
Total	**16**	**100%**	

** From 1 MT (1,000 Kg) RBD (Refined Bleached Deodorized) Palm Stearin = 1.156 KL (1,156 Liters) Biodiesel + 120 Kg Crude Glycerin*

*** From 1 MT (1,000 Kg) Buffalo Tallow = 1.156 KL (1,156 Liters) Biodiesel + 120 Kg Crude Glycerin*

**** From 1 MT (1,000 Kg) Acid Oil = 0.975 KL (975 Liters) Biodiesel)*

Source: BCG Analysis

Feedstock Potential (UCO)

The Government of India is taking various initiatives to increase the usage of biofuels in the country. The Government has also notified the National Policy on Biofuels-2018 (NPB-2018), amended in May 2022, to achieve 5% biodiesel blending in diesel by 2030. NPB-2018 has emphasized on using indigenous feedstock for biodiesel production and identified UCO as a potential source for biodiesel production. However, large quantities of UCO are being diverted for edible streams through various small eateries / vendors, which poses severe health risks to the citizens of India.

To promote UCO based biodiesel, OMCs, in collaboration with the Food Safety and Standards Authority of India (FSSAI), launched EOIs to procure biodiesel produced from UCO on 19th August 2019 on the occasion of "World Biofuel Day." The purpose of inviting this EOI was to encourage entrepreneurs to set up biodiesel plants from UCO processing plants and further utilize the existing potential of UCO based biodiesel in India. OMCs are periodically releasing EOIs, and as of now, 42 Letters of Intent (LOIs) have been issued, with 1st supply delivered in Feb 2021 (Table-4.7).

To streamline the UCO collection system, FSSAI has launched an initiative "Repurpose used Cooking Oil (RUCO)" that creates an ecosystem to collect UCO by authorized aggregators and

Under RUCO FSSAI implements triple 'EEE' strategy i.e. "Education" Enforcement" and "Ecosystem" to promote UCO:

- Education: Creating Awareness about UCO health hazards – "Eat Right campaign"
- Enforcement: Ensure disposal of UCO in Environmentally safe manner
- Eco-system: Creating a Robust & Sustainable business model for utilization of UCO

convert it into biodiesel. The ecosystem will ensure that the UCO does not re-enter into the food chain. To address the supply chain management issues, MoPNG constituted State Level Committees that prepare state/UT level plans for developing sustainable supply chain for UCO collection and further its availability to biodiesel plants.

Table-4.7: Status of UCO EOI Initiative (July 2022)

Parameter	Units	IOCL	HPCL	BPCL	Total
EOIs Received	No. of Plants	37	15	9	61
Capacity Proposed in EOIs	TPD	616	155	138	909
LOIs issued	No. of Plants	31	7	4	42
EOIs under evaluation	No. of Plants	1	8	5	14
LOIs awarded + under evaluation	No. of Plants	32	15	9	56
Expected Biodiesel Production against LOI issued	TPD	579	130	110	819
Biodiesel Plants commissioned	Nos.	3	0	0	3

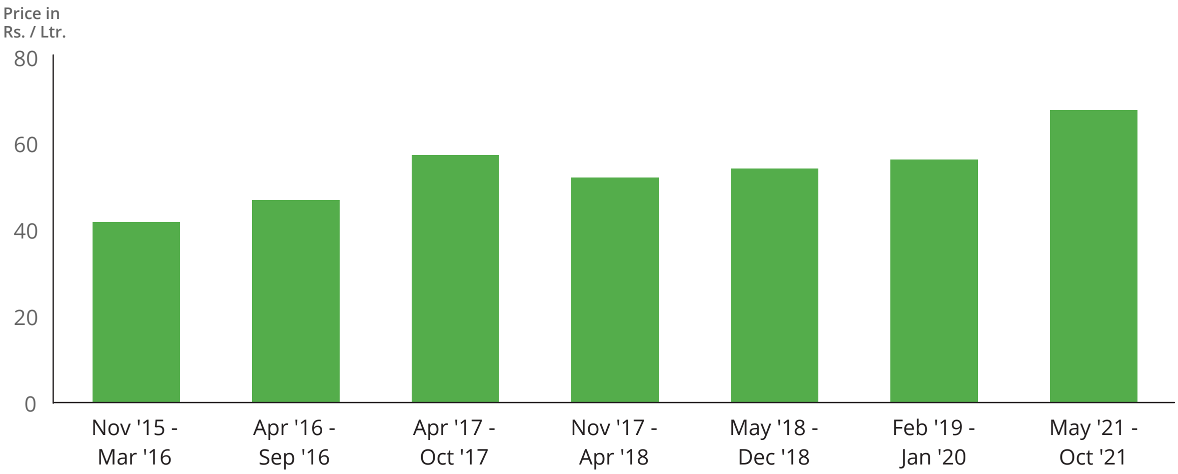
Source: Tracking 42 EOIs floated by Indian OMCs

Bio-diesel Procurement

Oil Marketing Companies have been procuring bio-diesel since 2015 at competitive prices, initially through public tender and later through fixed price according to market.

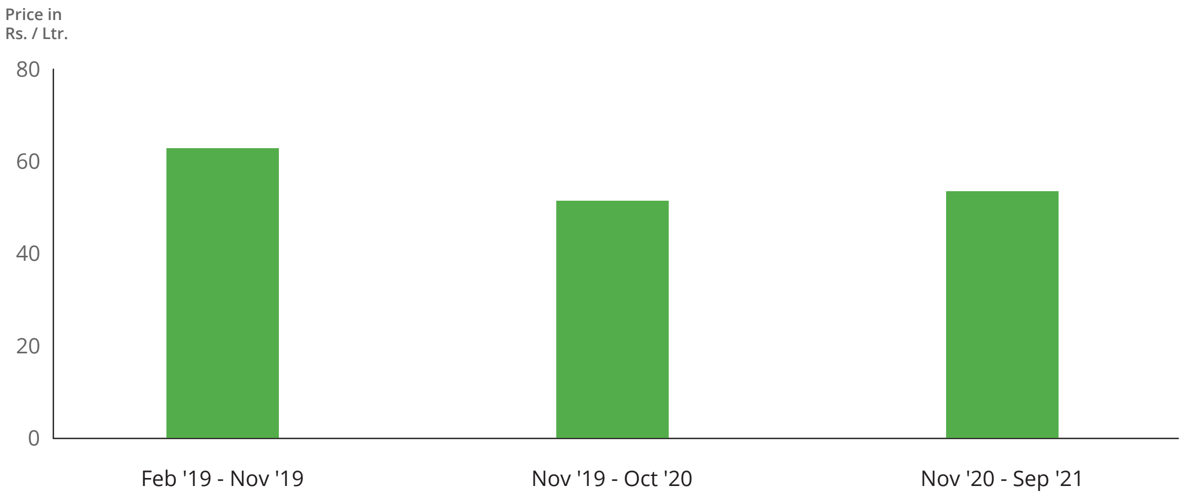
The problems encountered under the existing situation of using tree borne oilseeds of forest origins as feedstock include: collection from scattered locations, high dormancy and problems in picking and harvesting in avenue and forest plantations, non availability of quality planting material or seed, limited period of availability, unreliable and improper marketing channels, lack of post harvest technologies and their processing, non remunerative prices, the wide gap between potential and actual production, absence of state incentives promoting bio-diesel as fuel, and economics and cost-benefit ratio

Exhibit-4.3: Non-UCO Biodiesel Base Price as per OMC figures



Source: BCG Analysis

Exhibit-4.4: UCO Biodiesel Base Price (as per OMC figures)



Source: BCG Analysis

CHALLENGES

Biodiesel can be obtained from different feedstocks like vegetable oils, algae, microbial oil and animal fats. Biodiesel obtained from different feedstocks have various purity and composition.

The main step for the biodiesel production is selection of feedstock, which influences various factors, like purity of biodiesel, cost, composition and yield.

Exhibit-4.5: Key variables having an effect on production & availability of Biodiesel

1 AVAILABILITY OF RAW MATERIALS

The lack of an integrated and dedicated supply chain for raw materials like UCO and acid oil restricts the availability of raw materials for biodiesel production. The prices of feedstocks have also risen considerably in the post-pandemic era. Although palm stearin is currently the primary feedstock for production, it is majorly imported from Southeast Asian countries, which does not help improve India's energy security. Similarly, the export of animal tallow has deprived availability in the local market for biodiesel production.

2 HIGH PRICES IN THE INTERNATIONAL MARKET

Internationally, especially European countries, offer much higher prices for raw materials like UCO and animal tallow than that offered in India, which has increased the export of these materials and resulted in a supply deficit within the country.

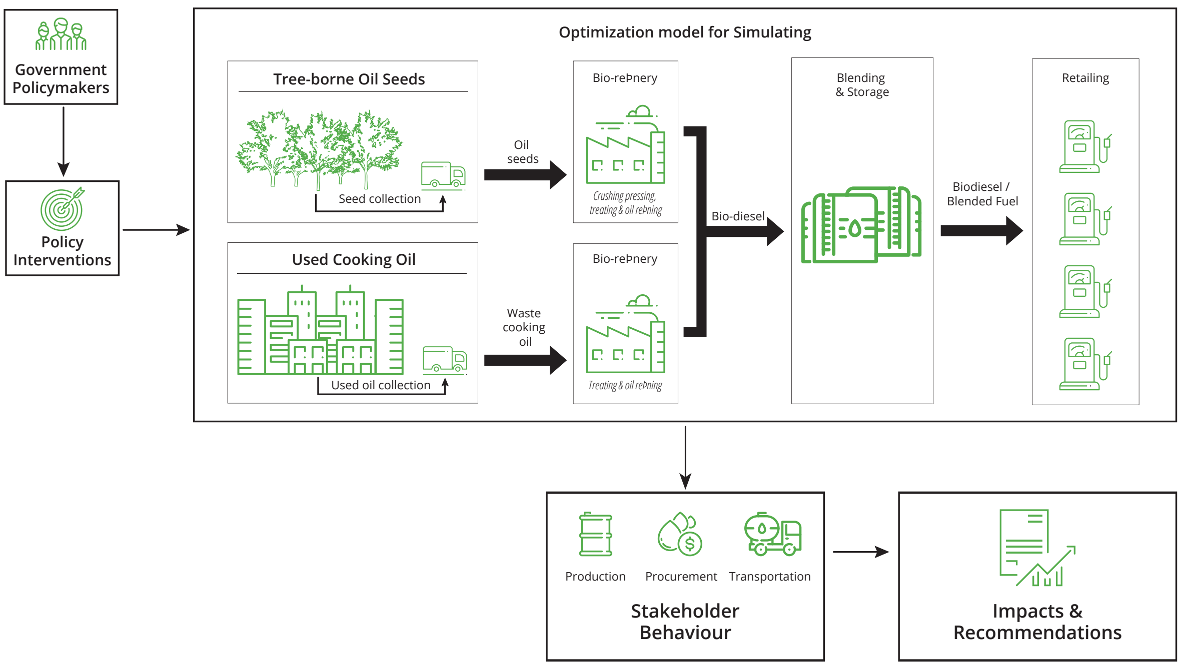
3 LACK OF INCENTIVES TO MANUFACTURERS

Auto manufacturers are not incentivized to make superior engines compatible with biodiesel, thus hampering the scale up of biodiesel production.

KEY POLICY INTERVENTIONS

- *Promote research on new feedstocks to ensure steady supply:* Explore possibility of utilizing new feedstocks like algae oil to reduce dependence on existing sources which are vulnerable to external factors (Palm Stearin Oil) and inconsistent in supply (Animal Tallow, Acid Oil, UCO and TBO).
- India has enormous potential for oilseeds of *Tree Borne Oil (TBO) and short gestation crops.* The country has over 190 million ha. of cultivable land. India has irrigated nearly 50-60 million ha of land where 2-3 crops are grown in a year. For various reasons, more than 40 million ha have been barren for years. For the rest of the arable land, the cultivation of the crop is under rain-fed conditions, and only one crop is grown in the monsoon rendering the land unproductive for 7-8 months in a year. With the right interventions, significant tracts of such land rendered unproductive can be brought under the cultivation of short gestation non edible oil seed crops.
- *Encourage direct sale without blending:* Direct sale of biodiesel is recommended as compared to blending, as blending has proven to be economically unviable. The blending mandate of 5% as per NPB-18 may be reviewed in view of the same. There is a need to promote additional channels like utilization for ATF and exports where returns are remunerative.
- *Reduce cost burden for customers:* OMCs are advised to sell the biodiesel directly as B100 at retail outlet as blending invites VAT over GST, making it costlier. With direct sale this is avoided, and biodiesel shall be a bit cost competitive in comparison to HSD.
- *Establish mandate for use of UCO:* FSSAI to mandate use of UCO for biodiesel production. Enforcement to be made in such a way that UCO is collected and made available with biodiesel manufacturers.
- *Streamlining of UCO aggregation:* Policies for facilitating aggregation of UCO and restricting diversion to non-biofuel uses need to be strengthened and enforced. The RUCO app launched by FSSAI on World Biofuel Day 2018 needs to be re-operationalized for tracking and monitoring.

Exhibit-4.6: The Biodiesel Value Chain Considerations



CBG (COMPRESSED BIOGAS)

Photo Credit: Adobe Stock

INTRODUCTION

Waste and bio-mass sources like agricultural residue, cattle dung, sugarcane press mud, distillery spent wash, municipal solid waste, sewage treatment plant waste, etc., produce biogas through the process of anaerobic decomposition. The biogas is purified to remove hydrogen sulphide (H_2S), carbon dioxide (CO_2), & water vapour, and compressed to form Compressed Biogas (CBG) or Bio-methane, which has a methane (CH_4) content of more than 90%.

Biogas can serve as a suitable replacement for imported fossil natural gas with close to net zero emissions while boosting energy security supported by competitive economics. The breakeven natural gas price for favorable production is <US$ 5/MMBTU vs. long term average of ~US$ 10/MMBTU. Biomethane (purified biogas) can be injected into natural gas pipelines and marketed as a low carbon fuel. By avoiding landfill emissions from biomass and putting them to productive use, biogas supports India's efforts to move towards net zero. As a byproduct of biogas production, Fermented Organic Manure (FOM) and Liquid Fermented Organic Manure (LFOM) generated in the biogas production process have significant fertilizing value. FOM can be enriched to Phosphate Rich Organic Manure (PROM), which can reduce India's import dependency on phosphate fertilizers (55% of the total). As an organic fertilizer, PROM further supports India's net zero goals and helps reduce water pollution. The use of FOM / LFOM / PROM will not only help protect soil health, promote organic/natural farming, and reduce chances of water contamination through chemicals but will also be an economically attractive proposition reducing imports and consequential subsidy on chemical fertilizers.

Table-4.8: CBG Specification as per IS 16087: 2016 Standard

S. No.	Characteristic	CBG	CNG
1	Methane, minimum (v/v %)	90%	90%
2	Carbon Dioxide, maximum (v/v %)	4%	3.5% (CO_2 and N_2)
3	Total sulphur, maximum	20 mg/m³	20 mg/m³
4	Moisture, maximum	5 mg/m³	5 mg/m³
5	O_2, maximum (v/v %)	0.5%	0.5%
6	(CO_2 + N_2 + O_2), maximum (v/v %)	10%	-
7	Other hydrocarbons, maximum (v/v %)	-	10%

Source: Bureau of Indian Standards

OUTLOOK

As per the IEA, around 3.5 Mtoe of biomethane is produced worldwide. The vast majority of production takes place in European and North American markets, with some countries such as Denmark and Sweden having more than 10% share of biogas/biomethane in their total gas sales. Countries outside Europe and North America are catching up quickly. Biomethane represents about 0.1% of natural gas sales today; however, an increasing number of government policies are supporting its injection into natural gas grids and for decarbonizing transport.

The global biogas market is expected to grow at 6-10% p.a. by 2040, with bio-methane expected to be the fastest sub-segment.

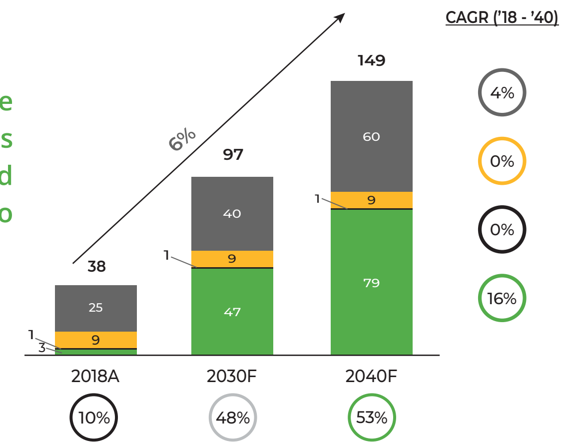
Stated Policies Scenario (STEPS)

The Stated Policies Scenario (STEPS) is a scenario in which Covid-19 is gradually brought under control in 2021 and the global economy returns to pre-crisis levels in the same year. This scenario reflects all of today's announced policy intentions and targets, insofar as they are backed up by detailed measures for their realization.

Power & heat are the largest applications today but upgraded bio-methane set to lead by 2030

STEPs scenario predicts a CAGR of 6% for Biomethane till 2040 with usage of biogas for both power & heat continuing to maintain a significant share.

Exhibit-4.7: Biogas consumption under STEPS (MTOE)



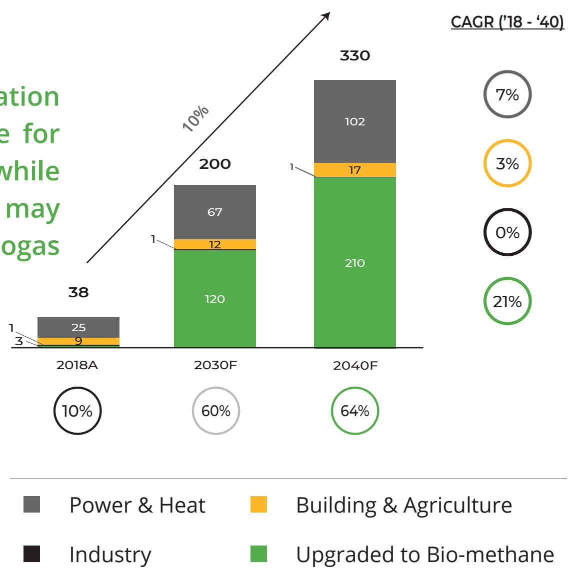
Sustainable Development Scenario (SDS)

In the Sustainable Development Scenario (SDS), a surge in clean energy policies and investment puts the energy system on track to achieve sustainable energy objectives in full, including the Paris Agreement, energy access and air quality goals. The assumptions on public health and the economy are the same as in the STEPS.

Deep decarbonisation is a strong upside for bio-methane, while power and heat may use more direct biogas

SDS scenario predicts a CAGR of 10% for biomethane till 2040 with deep decarbonization driving increased conversion to pure biomethane.

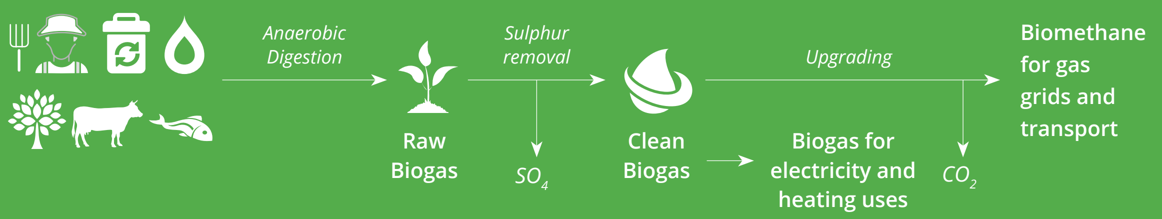
Exhibit-4.8: Biogas consumption under SDS (MTOE)



Source:

IEA 2020, Stated Policies (STEPS) & Sustainable Development (SDS) Scenarios; "Outlook for biogas and biomethane: Prospects for organic growth"

Exhibit-4.9: Compressed Biogas (CBG) Production Process



Source: BCG Analysis

INDIAN BIOGAS MARKET

Regulatory History

The Ministry of Road Transport and Highways, Government of India, vide the Gazette Notification no. 395 dated 16.6.2015, has permitted the usage of CBG for motor vehicles as an alternative to CNG. CBG can be used in vehicles using CNG fuel without making any modification to the vehicle. CBG has a high potential to replace CNG in automotive, industrial as well as commercial areas, given the abundant biomass availability within the country.

'SATAT' (Sustainable Alternative Towards Affordable Transportation) initiative on CBG was launched by the Hon'ble Minister of Petroleum & Natural Gas on 1.10.2018. The scheme envisages production of 15 MMT CBG & 50 MMT of manure from 5,000 plants. Under SATAT scheme, Oil & Gas Marketing Companies (OGMCs) viz. IndianOil, HPCL, BPCL, GAIL and IGL have been inviting EOIs from potential investors / entrepreneurs to procure CBG.

Salient features of the SATAT scheme
(adapted from the Expression of Interest floated by OMCs)

- Plant owner shall be responsible for installation, operation & maintenance of plant. OGMCs shall offtake CBG from the plant.
- OGMCs shall execute a Commercial Agreement of 15 years with the CBG Plant owner, to be extended on mutual consent.

The National Policy on Biofuels announced in 2018 by the Government of India put thrust on the production of advanced biofuels such as 2G ethanol, CBG, Waste to Fuels, drop-in fuels etc., through the utilization of indigenous feedstocks.

The Government of India has set a target to increase the share of gas in the energy mix from the current levels of about 6.5 percent to 15 percent by 2030 to make India a gas based economy. CBG can form a critical domestic supply source to contribute to this build-up.

Production of CBG shall increase the green energy mix, reduce import dependence, create employment, especially in semi urban and rural areas and reduce pollution. This will create value and employment in the rural economy across the supply chain, from biomass collection to plant operation. CBG has zero associated carbon emissions. The usage of CBG shall assist in achieving the climate change goals of India as per the Paris Agreement 2015.

The production of CBG is in alignment with Government of India schemes like Atmanirbhar Bharat, Make in India and Swachh Bharat and is also in alignment with the Gobardhan Scheme to effectively utilize cattle dung.

TECHNOLOGY

There are various technologies available for production of CBG. Anaerobic Digestion is used for the production of biogas which includes technologies like continuous stirred tank reactor (CSTR), plug flow, 2-stage reactors, Upflow Anaerobic Sludge Blanket (UASB), etc. After the production of biogas, hydrogen sulphide is purified through ferric chloride, iron chelate, biological process, activated carbon, etc.

Carbon dioxide purification technologies like chemical scrubbing, water scrubbing, Pressure Swing Absorption and Membrane Separation are used for the purification of carbon dioxide. The gas is compressed through a compressor. There are various national and global entities providing technologies for existing & upcoming CBG plants.

Pipeline Transportation: Biogas manufacturers can leverage existing and future Natural Gas (NG) pipeline network for cost effective transportation to consumption hubs. With about 98% of country's population to be covered by the CGD network post implementation of ongoing CGD rounds, issues relating to connectivity and off-take of biogas will be eliminated to a large extent.

FERMENTED ORGANIC MANURE

Fermented Organic Manure (FOM) produced varies from 15-30% of the feedstock of the CBG plants. FOM is useful to maintain soil health, particularly organic carbon, which helps microflora to flourish. It is a source of nitrogen (N), phosphorus (P), and potassium (K) and also has essential micro and macro nutrients which are vital for the balanced growth of plants. Creating an effective marketing strategy for FOM is critical for CBG Plants. The promotion of FOM can create an ecosystem of organic / natural farming in the country. Further, FOM can be enriched to Phosphate Rich Organic Manure (PROM), which can reduce India's import dependency on phosphate fertilizers.

FEEDSTOCKS FOR CBG

The various feedstocks of biogas are waste and bio-mass sources like agricultural residue, cattle dung, sugarcane press mud, municipal solid waste, etc. CBG production varies as per technology, feedstock quality, etc. The indicative feedstock-wise CBG potential is described below:

Table-4.9: Feedstock wise potential for production of CBG

Feedstock	Feedstock Requirement for production of 1 TPD CBG as per Conventional Technology
Agriculture Residue	10 ton
Press Mud	25 ton
Municipal Solid Waste	20 ton
Cattle Dung	50 ton
Napier Grass	10 ton

Source: Discussion with CBG Plant owners/entrepreneurs under the SATAT initiative

- **Agriculture Residue**

The agriculture residue, like paddy straw, wheat straw, etc., needs to be aggregated and collected from the fields. For this purpose, equipments like stubble shaver, raker, baler, trolley, tractors, etc. are required. A special dedicated scheme, Sub-Mission on Agricultural Mechanization (SMAM), was introduced by the Government of India in FY 2014-15. Distribution of various subsidized agricultural equipment and machines to individual farmers is one of the activities under the scheme. Promotion of ex-situ management of crops like production of CBG shall reduce agricultural emissions and use the waste agricultural residue to produce CBG and FOM.

- **Municipal Solid Waste (MSW)**

  The segregated organic portion of MSW, food waste, vegetable and fruit waste is a good input material for CBG production. Presently, bio-degradable waste is used for composting, where methane is released into the atmosphere. The same organic waste can be used for CBG production. Segregation at waste generation source has to be implemented for effective bio methanation of MSW.

- **Press Mud**

  Press mud is the compressed sugar industry waste produced during filtration of cane juice. Being a waste material, it is dumped, causing landfill emissions. Alternatively, this can be anaerobically digested to produce CBG.

- **Cattle Dung**

  There are a number of large and small gaushalas or cow shelters across India. The cattle dung from these gaushalas can be mixed with other feedstocks (considering the low yield of only cattle dung) to produce CBG.

- **Energy crop plantation**

  Energy crops like Napier grass can be cultivated on barren or unutilized pieces of land for the production of CBG.

ENABLERS INTRODUCED UNDER THE SATAT INITIATIVE

The following enablers/policy guidelines have been introduced for the propagation of the SATAT initiative:-

- **Financing of CBG Plants**

  Reserve Bank of India has notified the inclusion of CBG projects under Priority Sector Lending vide directives to banks dated 4.9.2020. By this notification, the banks are mandated to lend to the CBG sector also, along with other priority sectors, with adequate and timely credit. State Bank of India, Punjab National Bank, Canara Bank, Bank of Baroda and Union Bank have launched a product on the financing of CBG Plants under the SATAT scheme.

- **Solid & Liquid Fermented Organic Manure**

  FOM & LFOM are the byproducts of the CBG Plant and are considered to be an important source of revenue. As an enabling mechanism, FOM and LFOM produced from CBG Plants have been included under Fertilizer Control Order 1985.

- **Co-mingling of CBG with NG**

  MoP&NG has issued policy guidelines for co-mingling of CBG with NG in the CGD network.

- **State Level Committee for implementation and monitoring of SATAT Scheme for CBG**

  Presently, state level SATAT Committees have been formed in Haryana, Punjab, Uttar Pradesh, Chhattisgarh, Andhra Pradesh and Tripura. The committees coordinate with various state departments to provide state specific enablers for CBG Plants.

- **Pollution Clearance**

  CBG Plants producing FOM and LFOM as byproducts and not discharging any wastewater are included in the white category for pollution clearance.

- **Explosives License**

  The Petroleum & Explosive Safety Organization (PESO) has issued a notification dated 21.2.2022 stating that no separate approval or license is required from PESO for selling of CBG if an entity has obtained a license for selling of CNG and vice versa.

PROCUREMENT PRICE OF CBG

Procurement pricing of CBG was revised by OGMCs from 01.06.2022, are provided below:

- The minimum procurement price of CBG will not be lower than Rs. 46/kg + applicable taxes for the period up to 31.3.2029.
- The Retail Selling Price (RSP) of CBG in a market shall be at par with the RSP of CNG (as provided by the authorized CGD entity).
- The following price slabs have been decided as the procurement price of CBG delivered at OMC retail outlets situated at a distance of maximum upto 75 km (one way) as per IS 16087:2016 specification (or its latest version) and compressed at 250 bar pressure.

Table-4.10: Procurement price of CBG

S. No.	Retail Selling Price of CBG, including tax, in Rs. / kg		Procurement price of CBG, in Rs./kg	
	Lower Limit	Upper Limit	Without GST	With GST
1	-	Upto 70.00	54.00	56.70
2	70.01	75.00	55.25	58.01
3	75.01	80.00	59.06	62.01
4	80.01	85.00	62.86	66.01
5	85.01	90.00	66.67	70.01
6	90.01	95.00	70.48	74.01
7	95.01	100.00	74.29	78.01

Note:

i. For further increases in slabs beyond Rs. 100/kg, the procurement price will be extrapolated as per the above. If the RSP of CBG falls below Rs. 70/kg, there will be an immediate revision in the procurement pricing.

ii. Under MoP&NG policy guidelines on co-mingling of domestic gas for supply to CNG (Transport) and PNG (Domestic) of CGD, the biogas procurement price set by GAIL is Rs. 1,082/MMBTU (equivalent to Rs. 46/kg). Compression & CBG transportation charges of Rs. 8/kg are provided additionally.

Source: Oil Marketing Companies

CHALLENGES

- **Plant Costs:**

  As there are a small number of CBG Plants, equipment costs are higher due to a lack of economies of scale.

- **Feedstock supply:**

  There is a lack of a long term sustainable supply of feedstocks like biomass and waste at viable rates. The non assurance of a steady supply of feedstock is one of the major issues in setting up CBG Plants and makes the projects non bankable.

- **Technical & Infrastructure Barriers:**

  The segregation of organic and non organic waste is not done in urban households resulting in low quality organic feedstock for biogas plants based on MSW as feedstock. Due to improper segregation, dust and inert material also exist to varying degrees in the feedstock. In this case, sorting of wastes needs to be done before digestion at the plant, which further increases the overall generation cost and complexity. Moreover, poor collection and unorganized transportation of wastes, especially in medium to small sized cities, increases the supply chain disruption risk.

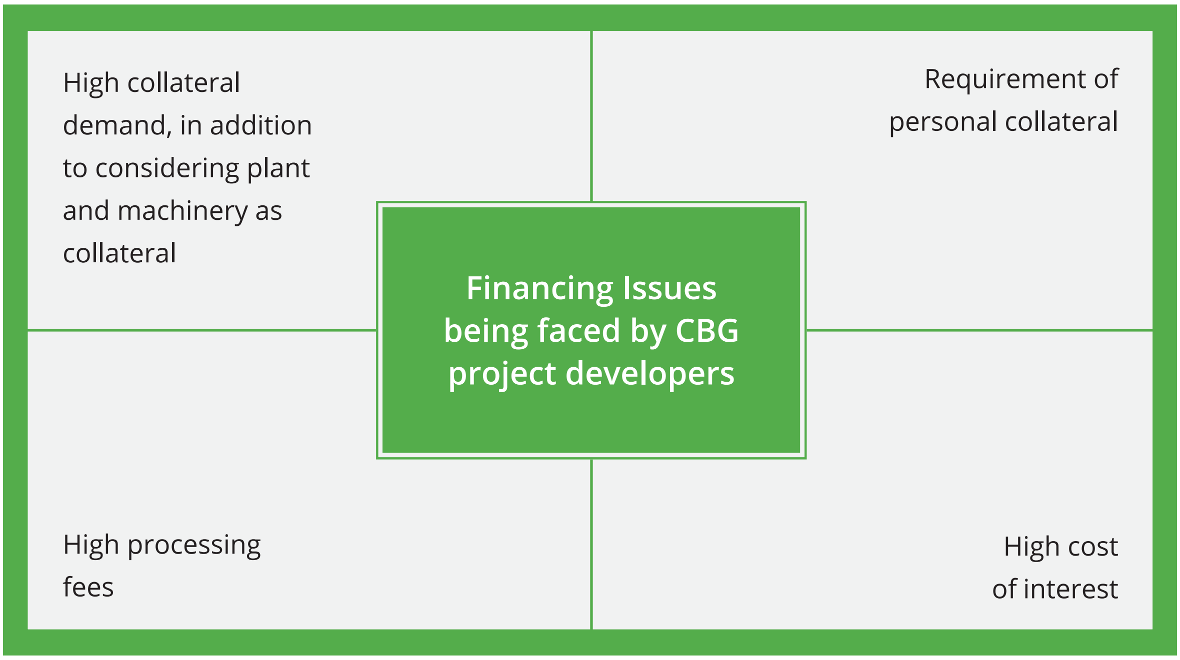
- **Marketing of FOM:**

  The FOM produced is about 3 times of CBG production and can be a major revenue source. There is no established mechanism for the sale of FOM / LFOM through major fertilizer companies, and agencies setting up plants have to work on their own. While there is a subsidy on chemical fertilizers, there is no subsidy on FOM/LFOM. Rather there are several restrictions like the requirement of a permit for transportation and sale from one state to another and a license for marketing etc. Therefore, FOM / LFOM produced is lying unsold with several of these plants.

- **Financing:**

  Financing projects is difficult because of the thin margin and perceived risks. The major risks perceived for CBG Plants are technology availability for CBG plants, feedstock supply chain including assurance on availability of quantities and rates in the long term and marketing / disposal of FOM, LFOM & CBG.

Exhibit-4.10: Financial issues faced by CBG project developers



POLICY INTERVENTIONS REQUIRED FOR THE CBG SECTOR

Enablers for creation of a biomass supply chain

- Providing subsidies on biomass aggregation and storage equipment under the SMAM and state specific schemes. Presently about 50% subsidy is available for biomass aggregation & storage equipment under the SMAM scheme. State governments may provide an additional subsidy of a minimum of 30% to make the procurement of equipment more viable. The subsidy may be provided upfront during the procurement of equipment and may also be extended to corporates setting up CBG Plants.
- Engagement of FPOs/CHCs etc., for aggregation and storage of biomass.
- Awareness and promotion activities for biomass aggregation in the catchment area.
- Biomass aggregation equipment (Cutter+ Racker+ Baler) deployment in the catchment area of CBG plants by state governments.
- Identification and notification of biomass clusters for CBG plants and other biomass based biofuel projects and grant of an exclusivity area for a long enough tenure.
- Incentives on operating expenses of biomass aggregation and storage equipment @Rs. 1,250 / ton of biomass by state governments.
- Allotment of panchayat / revenue land for a decentralized storage facility for the development of biomass depots.

Enablers for other feedstocks

- **MSW**

  All urban waste in smart cities and cities with > 1 Mn population should be directed to biogas production. Land and segregated MSW may be provided free of cost to CBG plants. MSW has to be segregated at source for CBG production.

- **Press Mud**

  Providing press mud at sustainable rates on long term contracts for CBG plants. Sugar mills should execute agreements of a minimum of 20-25 years with CBG plants to supply press mud with a price escalation clause. Environmental law may be enforced to ensure that the press mud is not burned or discarded without treatment.

- **Cattle Dung**

  Providing cattle dung free of cost through long term contracts with CBG Plants.

- **Sewage Waste**

  All Sewage Treatment Plants to be provided digesters for biogas production.

CBG Market Development

- Provide CBG blending mandates to all CGD entities marketing CNG and PNG.
- Promotion of CBG and CNG vehicles in locations with upcoming CBG plants and conversion of existing vehicles and tractors.
- Issuance of comprehensive guidelines on marketing of CBG through CNG outlets and vice versa. Dedicated “Green Hours” can be designated for undertaking sale of CBG through CNG outlets.

Manure Marketing

- Department of Fertilizers may provide market development assistance for selling FOM @ Rs 1,500 / ton.
- Mandatory offtake arrangement of bio manure from CBG Plants @ Rs 5000-6000/ ton by chemical fertilizer companies with minimum mandated offtake of bio manure as a percentage of chemical fertilizers in a ‘Basket Approach.’
- As per guidelines Ref. No. 12-17/86 - Fert. Law of the Ministry of Agriculture, Government of India, state governments have been empowered to exempt dealers marketing fertilizers in small packaging, weighing not more than 5 kg (net) under Fertilizer Control Order 1985. As per guidelines Ref. No. 1-1/90 dated 12.2.1990 of the Ministry of Agriculture, Government of India, dealers having stock of fertilizers up to 10 MT are exempted from obtaining a certificate of registration under Fertilizer Control Order 1985.
- Creation of a market ecosystem for bio manure and promotion of FOM
- Exemption from retail license requirement for the sale of FOM in small quantities, including packages less than 5 Kg and stock less than 10 MT at any given time.
- Extension activities on bio manure by the Department of Agriculture, Agricultural Universities, and Krishi Vigyan Kendras, including awareness generation and inclusion of the package of practices.
- Awareness of soil health improvement to be promoted at training meetings for farmers.
- Creation of natural farming and organic farming ecosystems. The Government may declare the vicinity of CBG Plants as ‘Green Zones’ where only FOM may be used for organic and natural farming.
- Creation of a national brand & certification for organic and natural food produced by FOM.

Financing

- Extending Central Financial Assistance (CFA) for all commissioned CBG Plants as well as upcoming CBG Plants for the next 10 years.
- Providing Production Linked Incentive (PLI) @ Rs. 10/kg of CBG to encourage production.
- Financial incentives like access to credit, accelerated depreciation, long term land leases and tax holidays would help to attract private investment to the CBG sector

Land & Utility

- Providing panchayat / revenue land directly to project developer at nominal prices on a long-term lease. Land shall be used for feedstock storage and for establishing CBG plants.
- Providing subsidized electricity for CBG Plants, preferably at domestic rates.

Other State Government specific Enablers

- Creation of state level SATAT Committees for all states with members from departments dealing with agriculture, urban development, fertilizer marketing, renewable energy, animal husbandry, sugarcane, cooperatives, panchayati raj, pollution control, etc., as well as OGMCs and fertilizer marketing companies.
- State specific subsidies for CBG Plants during the initial phase.
- Facilitate CBG plants to obtain necessary permissions, registrations, approvals etc., through an easier process.
- Provide a single window clearance for CBG plants on all statutory approvals with a one-time nominal fee.
- Assure preferential supply of feedstock for CBG plants to ensure their long term viability.

Research

- Promotion of research & development of CBG production technologies and its deployment, supported by government funding.
- Development of additives for the enrichment of FOM.
- Creation of model CBG Plants by and with backup support from technical universities across the country.

Training & Development

- Courses on CBG technology, feedstock management, manure enrichment, marketing, and O&M in state universities and technical and agricultural institutes.

Emission Trading

- CBG plants assist in the mitigation of carbon emissions. They also help reduce emissions due to crop burning and divert waste from landfills. Accordingly, we should book and claim or provide a trade mechanism for carbon trading in CBG Plants. The emissions saved through the injection of CBG at a certain location may be traded for emission mitigation at another location.

Chapter 5

THE INDIAN COOKING FUEL SCENARIO

In this section

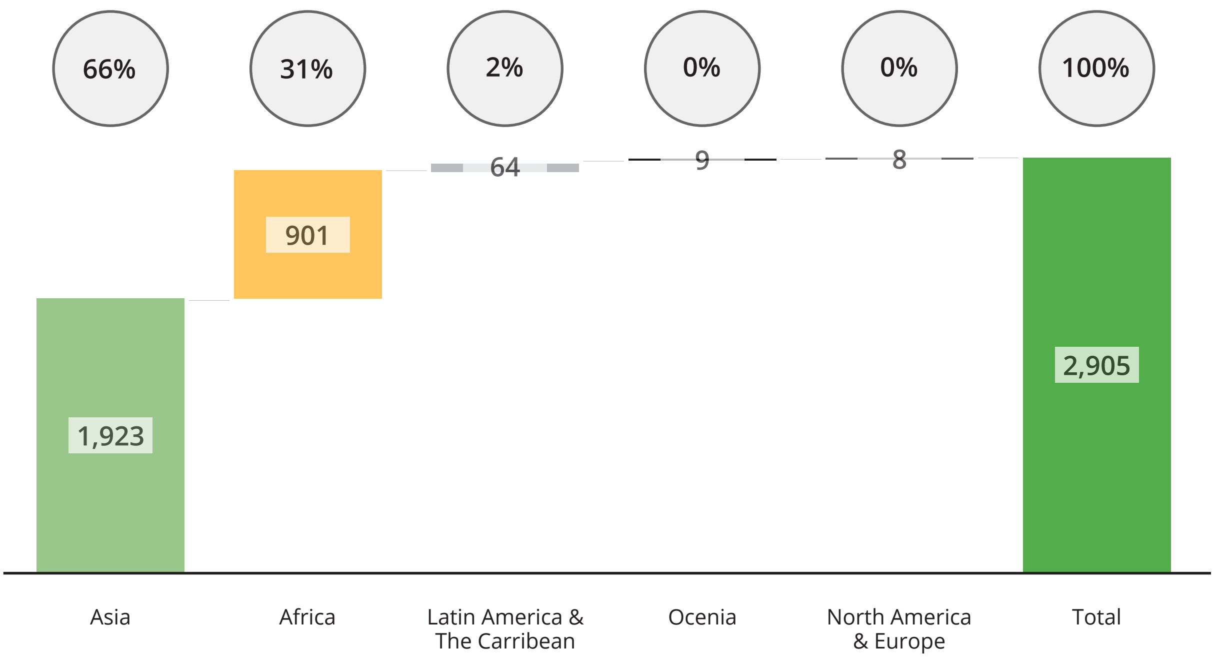
CLEAN COOKING FUEL

Energy is used for multiple household applications, ranging from lighting and heating to cooking. Almost 3 billion of the world's poorest people still rely on solid fuels (wood, animal dung, charcoal, crop waste, and coal) for their cooking and heating needs.[1] The use of such fuels results in exposure to high levels of air pollution, resulting in approximately 4 million premature deaths annually from respiratory and cardiovascular diseases and cancer[2]. It is thus crucial for the world to move to alternate ways of cooking and energy generation to promote the welfare of the masses.

Clean cooking fuel has been on the development agenda for decades. But only recently has the topic become a major priority on the global development agenda as part of UN Sustainable Development Goal (SDG) 7, which is to ensure affordable and clean energy for all by 2030[3].

While there is no universally agreed-upon definition of clean cooking energy, the term refers to cooking solutions that result in low or no household air pollutants (particulate matter and carbon monoxide) and outdoor air pollution in the form of black carbon emissions. The World Health Organization defines clean cooking as the use of clean fuels such as liquefied petroleum gas (LPG), ethanol, biogas, solar power, and electricity, and improved technologies for cooking with them.

Exhibit-5.1: Region-wise breakup of people needing access to clean cooking fuel, million people



Source: Energy Sector Management Assistance Program, Tracking SDG 7: The Energy Progress Report, 2019

As can be seen, according to the database that tracks SDG 7, there are approximately 2.9 billion people without access to clean energy globally, of which about 66 % are in Asia, and around 31 % are in Africa. To meet the SDG of affordable and clean energy for all by 2030, it will be essential to solve the issue predominantly in these two regions.

[1] *World Health Organization, WHO guidelines for indoor air quality: Household fuel combustion, 2014*

[2] *International Energy Association*

[3] *UN Sustainable Development Goals*

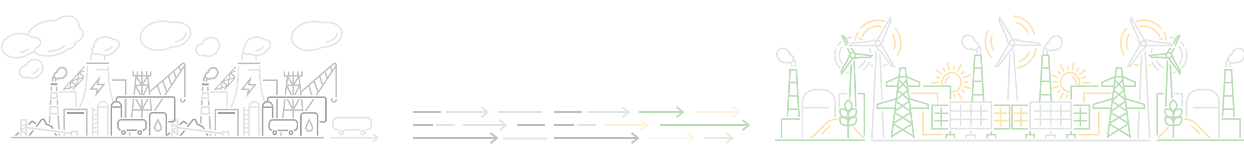
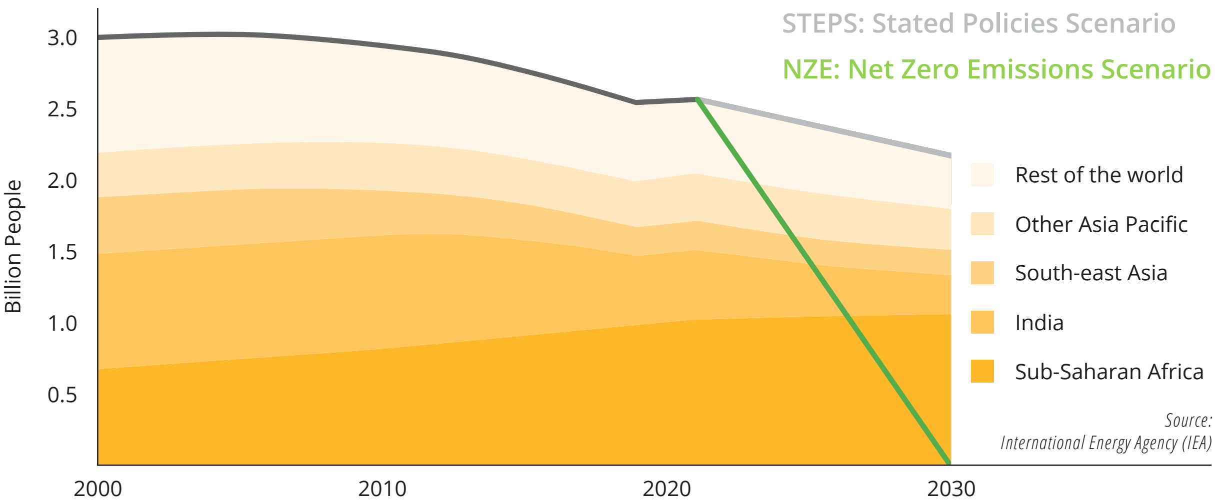
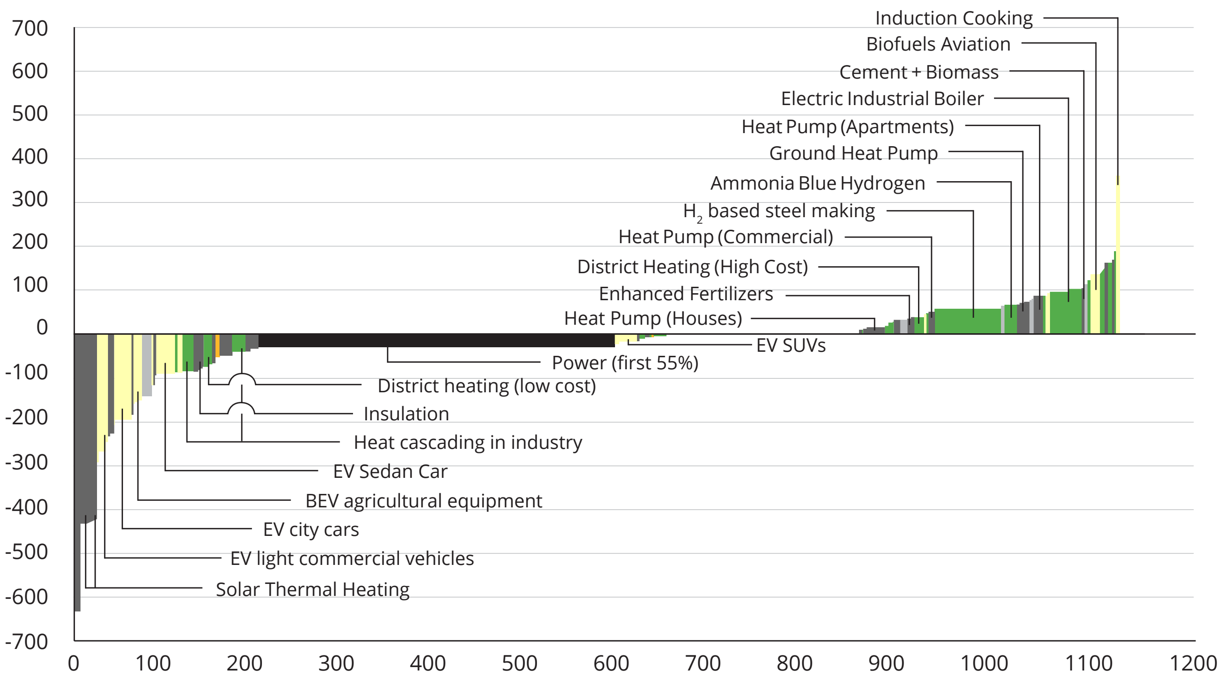


Exhibit-5.2: Population without access to clean cooking fuel



As seen from Exhibit-5.2, current projections and the International Energy Agency's policy scenarios show the world is not on track at the current pace to achieve universal access to clean fuels and technologies for cooking. It is expected that more people will have access to clean cooking fuels in Asia by 2030, but in Africa, the population without access to clean cooking fuels will, in fact, increase. The magnitude of the challenge will remain large and should be a priority in the future. Another priority area, specifically in the backdrop of net zero and climate change is the switch to clean cooking fuels. It is widely recognised that the abatement of CO_2 emissions from cooking is among the costliest measures globally. Suitable R&D, commercialization and scaling-up of clean cooking fuels remains a necessary step to change this picture.

Exhibit-5.3: Abatement cost, € per ton of CO_2 equivalent



Source: McKinsey, Net-Zero Europe, November 2020

TYPES OF COOKING FUEL

Over the past few centuries, multiple fuels have been used for cooking. These range from solid fuels such as firewood to gaseous fuels such as LPG and biogas in the recent past.

Solid fuels can be categorized into renewable, biomass, and fossil fuels (the latter includes coal). Renewable solid biomass fuels include firewood, charcoal, dung, and agricultural residues. Fuelwood, including firewood and charcoal, is a renewable energy source only if the same amount of wood cut down is allowed to grow back. However, the usage of these sources represents enormous health costs. Except for harvesting, collecting, and chopping, firewood is otherwise unprocessed, whereas charcoal and agricultural residues and dung are often processed into briquettes, pellets, dung sticks, or plates. As is the case with all solid fuels, moisture reduces a fuel's net usable energy

Exhibit-5.4: Types of cooking fuel

Source: Adapted from Christa Roth, Micro-gasification: Cooking with gas from dry biomass, Deutsche Gesellschaft für Internationale Zusammenarbeit, February 2014 because the evaporation of water itself requires heat. So if not dried, the energy used in the process of evaporation of moisture is unavailable for increasing the fire temperature and takes longer, thus hindering the efficiency of cooking process. Thus, use of biomass, coal, firewood, charcoal, etc., is generally done only after being dried.

FIREWOOD

The oldest cooking fuel is firewood, a subcategory of fuelwood, which is defined by the Food and Agriculture Organization of the United Nations as "wood in the rough (from trunks and branches of trees) to be used as fuel for purposes such as cooking, heating or power production." Firewood can be categorized into hardwood and softwood. Compared to hardwood, softwood burns more quickly but generates less heat owing to lower energy (carbon) content relative to its volume. However, the energy content per weight is similar for all hardwood and softwood. The moisture content of firewood is a key determinant of its energy content. The drier the firewood, the less energy is required to evaporate the water, more efficient the combustion process, thus making more energy available for heating or cooking.

CROP RESIDUE

Agricultural residue is generated in large volumes after each harvest season and is often discarded as waste. In India, most agricultural residue and the residue from processing agricultural products are used as fuel in their natural state with limited pretreatment. Compared to fuelwood, crop residue typically has a high content of volatile matter and ash, lower density and energy values. Conventional stoves are primarily designed to burn firewood or charcoal. Micro-gasifiers are a good option for using agricultural residues, mainly in a densified way, because they can burn small energy carriers very efficiently.

COAL

Coal is not often used as a cooking fuel on its own. Instead, it is used in regions where cooking and heating fuel are combined. Due to its regional availability, coal is used for cooking in countries such as India and China. The coal used in households for cooking and heating varies in composition, form, and way of application. It comes in different forms, such as beehive briquettes, coal cakes, coal balls, and raw coal. The World Health Organization does not recommend using unprocessed coal in households due to carcinogenic emissions and toxic elements such as fluorine, arsenic, lead, selenium, and mercury, which are not destroyed by combustion.

KEROSENE

Among the liquid fuels, ranging from alcohols (such as ethanol and methanol), plant oil, and those generated from fossil fuels, kerosene is the most commonly used for cooking. Cooking with kerosene is popular because of its affordability, ease of storage, availability in small quantities, and convenience for cooking. However, using kerosene for cooking comes with serious disadvantages, as it is a highly polluting, flammable and is a non-renewable source. Due to a policy push by the Government to make superior cooking fuels like LPG and PNG widely available, kerosene usage in India is currently restricted to very few areas and is dwindling at an accelerated rate.

[4] *Miguel A. Trossero and Luiz Horta Nogueira, "Unified wood energy terminology," Food and Agriculture Organization of the United Nations, March 2001.*

DUNG CAKES

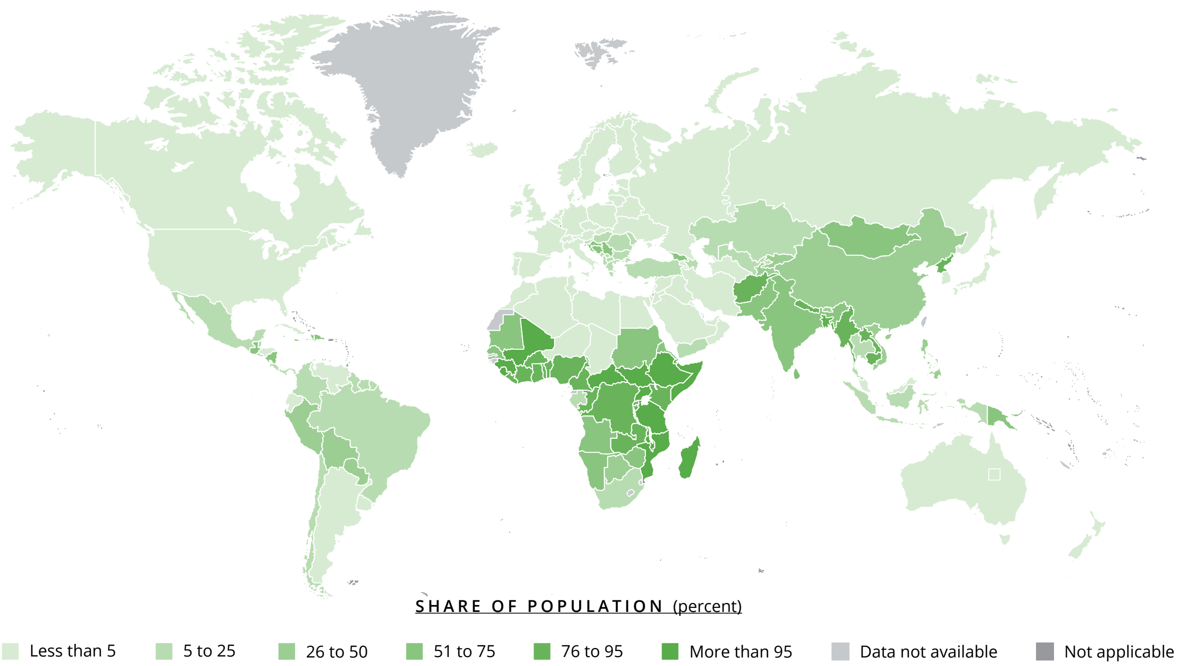
Made from the by-products of animal husbandry, dung cakes are traditionally used as fuel in India for cooking food in a domestic hearth called a chulha. They are made by hand by village women and are usually composed of cow or buffalo dung. An average-sized dung cake gives off 2,100 kilo-joules of energy. These are popular because they are efficient, readily available, and cheaper than most modern fuels, alleviate local pressure on wood resources, and cause less environmental pollution than most other fuels.

LIQUEFIED PETROLEUM GAS

LPG is a by-product of natural gas extraction and crude oil refining. It is a mixture of hydrocarbon gases, the most common being butane and propane. A mixture of air and LPG can be ignited if the amount of LPG in the air is between 2 and 10 %. The ignition temperature is above 380°C and thus serves as convenient cooking fuel. The main advantages of LPG are that it is a clean fuel and releases fewer pollutants and CO_2 than any other cooking energy source except electricity. Moreover, it heats quickly and provides much greater efficiency than even the best biomass stoves. LPG stoves can also be controlled more precisely, speed up cooking, and require practically no cleanup. Additionally, LPG can be transported, stored, and used almost anywhere. However, affordability for the masses, the potential risk of explosion (due to incorrect use or worn-out equipment), variable prices, etc., are still some of the reasons that have hampered large-scale adoption.

India predominantly used solid fuels for cooking until the late 2010s, but a recent push from the Government via incentives and subsidy programs has resulted in a shift toward LPG as the primary cooking fuel. Going forward, as India enables mass electrification, there will be a need and potential for electricity to become primary fuel.

Exhibit-5.5: Regional distribution of populations cooking with solid fuels



Source: Adapted from Christa Roth, Micro-gasification: Cooking with gas from dry biomass, Deutsche Gesellschaft für Internationale Zusammenarbeit, February 2014

CORRELATION BETWEEN ELECTRIFICATION AND COOKING

Electrification solves part of the clean cooking fuel challenge, as some households are switching from traditional fuels to electricity for some of their domestic needs, such as lighting and cooking. Electrification of a household can reduce household CO_2 emissions by 32 to 36 kilograms per year and black carbon emissions by 225 to 455 kilograms of CO_2 equivalent per year.

Clean cooking technologies (such as solar cookers) are often used as an entry product in un-electrified households, followed by either a move to LPG-based stoves or electric stoves, depending on the rate at which these technologies are made affordable. As per the Energy Sector Management Assistance Program, few countries contribute to 80% of the population deprived of both electricity and clean cooking access across the world. It is thus essential to solve not only the issue of access to clean cooking fuel but also that of electricity penetration. In doing this, there is a potential to use electricity as the primary means for cooking, but it remains to be seen if that will be viable, given India's push for LPG use in recent years.

India has made tremendous investments in the area of ensuring the supply of cleaner cooking fuels. The Indian Governments efforts through the globally acknowledged Ujjawala scheme serve as a reference for others to address the situation at scale and with speed. As a cooking fuel, LPG is a superior option as compared to traditional biomass or cow dung, etc, which were widely prevalent as energy providers for cooking. Recent Indian Government push to increase the share of gas in the domestic energy mix, massive investments in pipeline expansion and coverage of about 98% of the population through the CGD network shall create necessary conditions for PNG to become another supply source of natural gas over time.

> *Electrification of a household can reduce household CO_2 emissions by 32 to 36 kilograms per year and black carbon emissions by 225 to 455 kilograms of CO_2 equivalent per year.*

Picture Credit: Adobe Stock

COOKING FUEL IN INDIA

Until recently, solid fuels like firewood, crop residue, and dung cakes were the mainstay of primary cooking fuels for most Indian households. In 2011, 70% of Indian households primarily relied on solid fuels to meet their cooking fuel needs.[5] For increased access to clean cooking fuel across India, the Indian government distributed subsidised LPG connections to more than 8 crore low-income households under the Pradhan Mantri Ujjwala Yojana (PMUY) program between 2016 and 2019.[6]

In May 2016, the Ministry of Petroleum and Natural Gas (MOP&NG), introduced the 'Pradhan Mantri Ujjwala Yojana' (PMUY) as a flagship scheme with an objective to make clean cooking fuel such as LPG available to rural and deprived households. These households were dependant on traditional cooking fuels such as firewood, coal, cow-dung cakes etc which have detrimental impacts on the health of rural women and the environment. The Scheme is being implemented by three Central Public Sector Oil Marketing Companies (OMCs) viz. IOCL, HPCL and BPCL.

The target under the scheme was to release 8 Crore LPG Connections to the deprived households by March 2020. This target was achieved on 7th September 2019 when the Hon'ble Prime Minister of India handed over the 8th Crore LPG connection in Aurangabad, Maharashtra. This scheme has contributed towards increasing LPG coverage from 62% on 1st May 2016 to 99.8% as on 1st April 2021.

As on 1st September 2022, total connections released under PMUY are about 9.5 Crore. PMUY has helped take domestic LPG customers to over 30 crore. The program was hailed globally for both the scale and speed of implementation.

As of today, more than 70% of Indian households use LPG as primary cooking fuel, and 85% have LPG connections.[7] However, many households continue to use traditional solid fuels. In August 2021, Prime Minister Narendra Modi launched PMUY 2.0, aimed at providing free LPG connections to 1 crore additional low-income & migrant families in India.

Photo Credit: Adobe Stock

[5] Census of India, 2011

[6] Bhaskar, 2019

[7] Council on Energy, Environment and Water (CEEW)

INDIA'S CLEAN COOKING FUEL JOURNEY

In India, household air pollutants are the leading cause of air pollution-related deaths, which accounted for many lives lost in 2019.[8] The use of solid fuels for cooking affects the health of women and young children disproportionately, due to their higher exposure to the fumes.[9] Moreover, women spend a significant amount of time on fuel collection and preparation, a predominantly gendered activity, which further limits their opportunities for education, employment, and leisure activities.[10] Thus, access to clean cooking fuel is critical for achieving multiple developmental priorities, including improved health, gender equality, equitable economic development, and environmental protection.[11]

GOVERNMENT PROGRAMS FOR PROMOTING CLEAN COOKING FUEL

India has introduced several policies over the past few decades to displace the use of solid fuels (such as firewood, dung cakes, and crop residue) and increase the uptake of clean cooking fuel options, primarily LPG. Some of the specific initiatives are as follows:

Biogas

The National Project on Biogas Development, launched in 1981, was the first national policy for promoting biogas plants. It was renamed the National Biogas and Manure Management Programme in 2003. The program offers central financial assistance for domestic biogas plants. The Ministry of New and Renewable Energy provides support for training users, workers, and staff on the benefits of biogas plants and on regular operations and maintenance requirements. The program activities are carried out by nodal state departments and agencies, the Khadi and Village Industries Commission, and the Biogas Development and Training Centres.

Improved cook-stoves

The National Programme on Improved Chulhas, the first program to support improved cook-stoves, supplied 35 million chulhas from 1986 when it was launched to 2002 when it was discontinued.[12] In 2009, the Ministry of New and Renewable Energy launched the National Biomass Cook-stoves Initiative to continue R&D in improved cook-stoves, with several pilot projects being undertaken to improve stove efficiency and demonstrate the benefits of improved cook-stoves using existing technology.[13] It also included initiatives on carbon financing for biomass cook-stoves to reduce prices and increase affordability.

LPG

While the central government has been providing LPG subsidies in various forms since the 1970s, its latest efforts have been geared towards a more focused targeting of beneficiaries. The Direct Benefit Transfer for LPG attempts to curb leakages by transferring subsidies directly into the bank accounts of beneficiaries. The 'GiveItUp' campaign encouraged well-off households to voluntarily surrender their LPG subsidies so that the funds can be diverted to households that need them the most. However, the main thrust for improving LPG access among low-income and rural households came from the PMUY program, launched in May 2016. Under PMUY, the government distributed more than 80 million LPG connections at a subsidised cost.[14]

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[8] *Global Burden of Disease Study, 2019; Tripathi, 2020*

[9] *Arora, 2018*

[10] *Jha, Patnaik, and Warrier, 2021; Patnaik and Jha, 2020; Choudhuri and Desai, 2020*

[11] *World Health Organization, 2018*

[12] *Ministry of Non-Conventional Energy Sources, 2004*

[13] *Ministry of New and Renewable Energy, n.d.*

[14] *Press Information Bureau, 2019*

Piped Natural Gas (PNG)

The central government has been promoting the use of PNG in cities by allocating domestically produced gas (which is cheaper than imports) to city gas distributors at a uniform price. In 2014, the government revamped the allocation policy, giving city gas distributors first priority for receiving domestically produced natural gas and helping them keep PNG prices low.[15] To improve the penetration of PNG in other urban areas, the government allocates viability gap funding to city gas distributors if required. Policies that increase the availability of PNG in urban areas help reduce their reliance on LPG; this helps divert LPG to rural areas. With the completion of the 11th and 11A CGD bid round, it is expected that CGD will cover about 98% of the population, creating necessary conditions for piped gas to become an option for cooking energy for nearly entire Indian populace. Backed with suitable pricing and priority policies, PNG can potentially become dominant cooking fuel practically for all Indians, though some may upgrade to electricity.

Electricity-based cooking

At present, there is no national strategy to popularise or deploy electricity-based cooking options. Much of the success of such cooking solutions will depend on the achievement of the government's intention of electrifying all households with a 24/7 supply by 2022.[16] Current rural electrification programs such as Deen Dayal Upadhyaya Gram Jyoti Yojana look at electrification from a wider lens but need to give equal emphasis on the reliability of the electricity supply, which is *sin qua non* for use of electricity as an effective source of cooking energy.

While the Indian government has taken steps to increase the penetration of not only LPG, but also of alternatives like biogas, PNG, improved cook-stoves, and electricity-based cook-stoves, there has been limited focus on the sustained use of these options. Thus, going forward, the government should also start focusing on sustained use of intended source and eventually migrating to access to reliable availability of electricity to ensure India meets its decarbonization targets and also help address the aspirations encapsulated in Sustainable Development Goal-7.

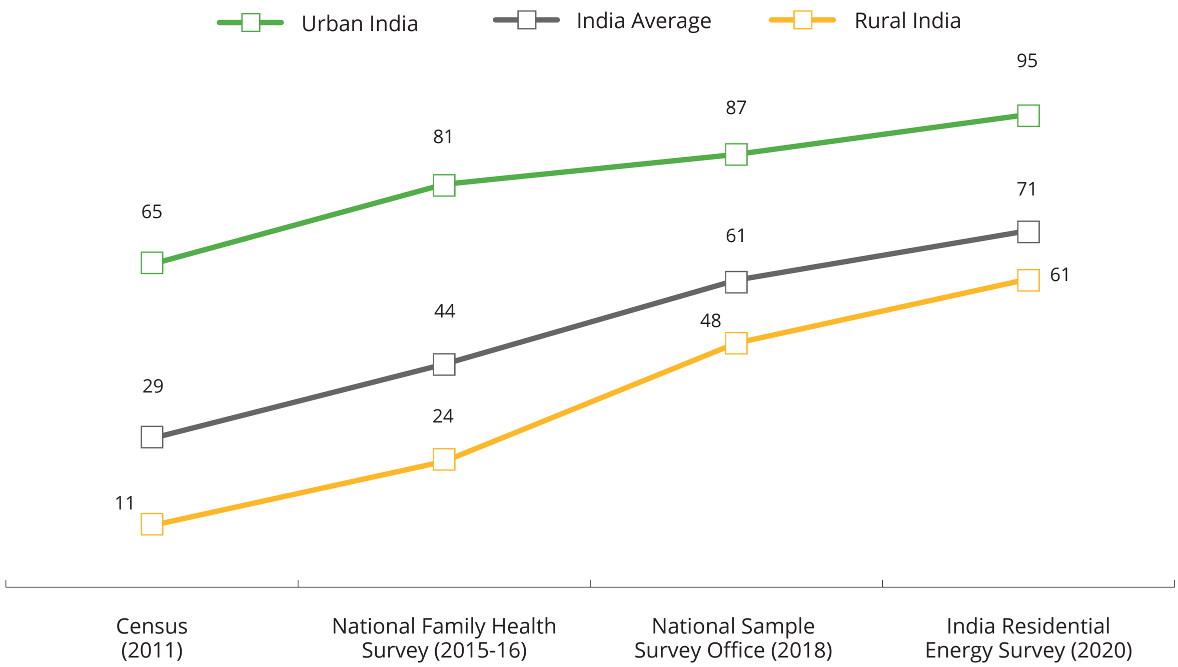
CURRENT PENETRATION OF CLEAN COOKING FUEL

While the share of Indian households using LPG or PNG as their primary cooking fuel is 71 percent, this is still lower than the share of households that own an LPG or PNG connection (85 percent). This number is higher for households in urban India, where 95 percent use LPG as their primary fuel, versus 61 percent of households in rural India. Having said that, the penetration of LPG use in rural India has improved significantly since 2011, when only 11 percent of the households used LPG as their primary cooking fuel. Apart from LPG and piped natural gas, electricity is also emerging as a key clean fuel, with 5 percent of the population using it today. With greater affordability and access to electricity across the country, this number will only increase going forward. With greater affordability and access to electricity across the country, number of uers of electricity as cooking fuel or an otion for the same will increase in future. However, half of the Indian households also continue to use firewood for cooking, and nearly a quarter report using dung cakes and other solid fuels. Most solid fuel users are in rural India, where despite 80 % of households having an LPG connection, 67 % still use firewood for at least some of their cooking needs. The practice of stacking solid fuels with clean fuels is a concern due to the resultant exposure to hazardous air pollutants in these households.

[15] *Press Trust of India, 2014*

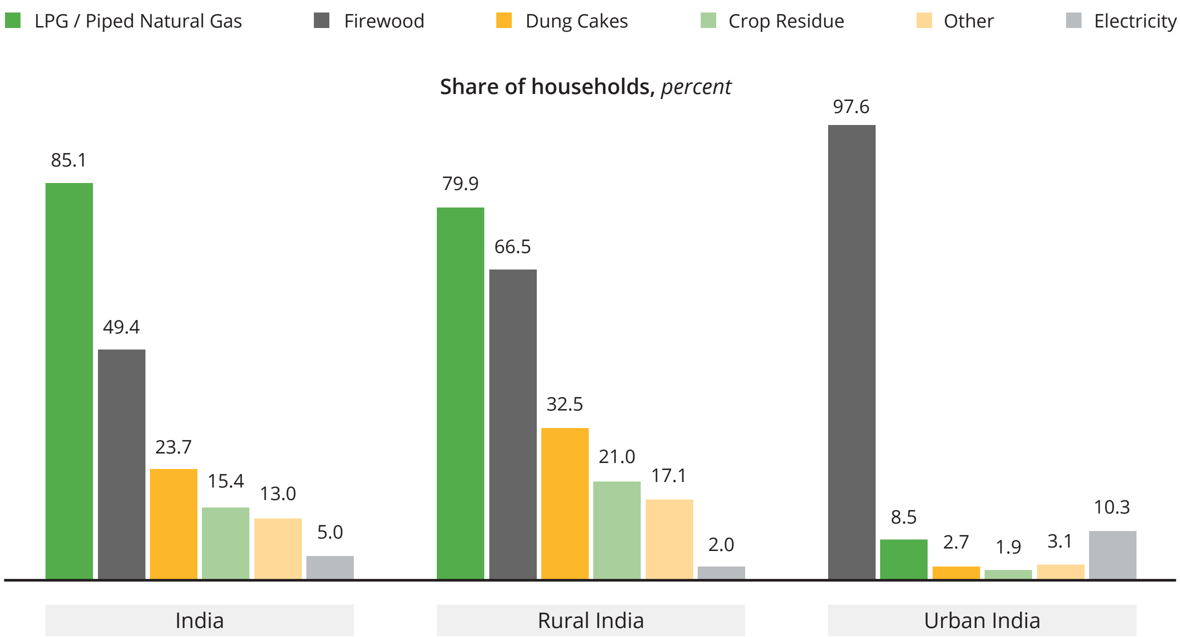
[16] *Press Trust of India, 2015*

Exhibit-5.6: Share of households using LPG as a primary cooking fuel, *percent*



Source: Council on Energy, Environment and Water, State of clean cooking energy access in India: Insights from the India Residential Energy Survey (IRES) 2020, 2021

Exhibit-5.7: Spread of cooking fuels across households



Source: Council on Energy, Environment and Water, State of clean cooking energy access in India: Insights from the India Residential Energy Survey (IRES) 2020, September 2021

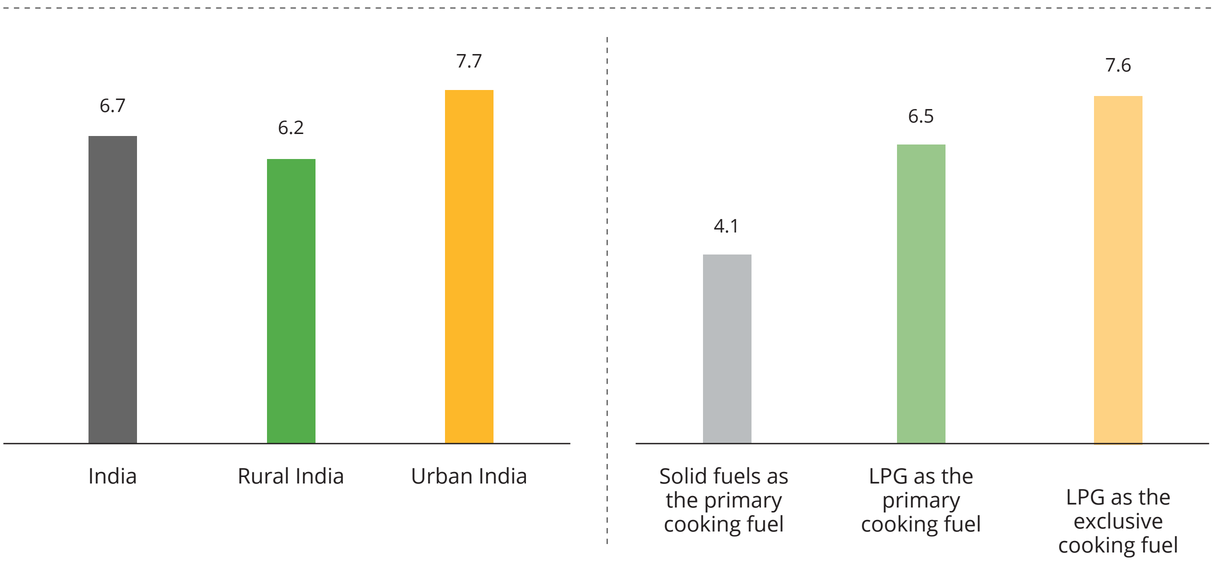
LPG SETUP IN INDIA

Of the list of currently available clean cooking fuels, LPG has emerged as the most viable option in India, at least in the short term emerging as the primary alternative in the switch from solid fuels before more eco-friendly solutions such as electricity and solar become viable. According to a report from the Petroleum Planning and Analysis cell of the Ministry of Petroleum and Natural Gas, India's public sector oil marketing companies (Indian Oil Corporation Limited, Bharat Petroleum Corporation Limited, and Hindustan Petroleum Corporation Limited) together have 305.3 million active LPG customers in the domestic category, whom 25,192 LPG distributors are serving. Public sector oil marketing companies have 202 LPG bottling plants all over India, with a rated bottling capacity of around 21.6 million metric tons annually. They sold nearly 18.8 million metric tons of packed domestic LPG from April to December 2021.

Public sector oil marketing companies enrolled 14.1 million new domestic customers from April to December 2021. During the same period, they added 109 distributorships. This infrastructure has helped achieve the current penetration levels of LPG, making it the most widely used primary fuel for cooking in India.

The LPG refill consumption rate is a valuable proxy to track household transition to clean cooking fuel. According to the Council on Energy, Environment and Water's India Residential Energy Survey (IRES), an average LPG-using household in India consumes 6.7 LPG refills (or around 95 kilograms of LPG) per year.[17] The refill rates are higher among urban households, despite smaller family sizes, primarily due to the low prevalence of stacking. A typical household that stacks LPG with biomass but uses the latter as the primary cooking fuel consumes four refills annually on average. On the other hand, households that consume LPG exclusively require seven to eight refills per year.

Exhibit-5.8: LPG refills per year (average numbers consumed)



Source: Council on Energy, Environment and Water, State of clean cooking energy access in India: Insights from the India Residential Energy Survey (IRES) 2020, September 2021

[17] *Sunil Mani, Shalu Agrawal, Abhishek Jain, and Karthik Ganesan, State of clean cooking energy access in India: Insights from the India Residential Energy Survey (IRES) 2020. New Delhi: Council on Energy, Environment and Water, September 2021.*

KEY NUMBERS ON INDOOR AIR POLLUTION AND RELATED IMPACTS

~1/3rd

Global population cooks using open fires or inefficient stoves fuelled by kerosene, biomass (wood, animal dung and crop waste) and coal, which generates harmful household air pollution.

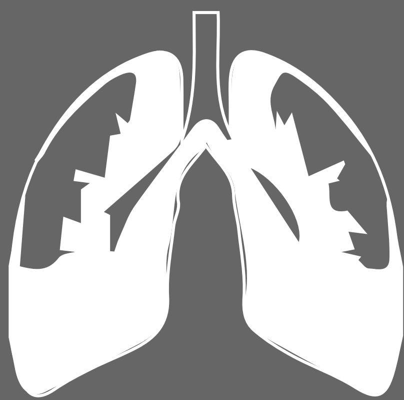
Women & Children,

typically responsible for household chores such as cooking collecting firewood, bear the greatest health burden from the use of polluting fuels and technologies in homes.

Household air pollution exposure leads to

many non-communicable diseases

including stroke, ischaemic heart disease, chronic obstructive pulmonary disease (COPD) and lung cancer.



3.2 million

Estimated deaths per year in 2020 due to household air pollution

2 lakh+

Annual deaths of children under the age of five from indoor air pollution

Adapted from WHO 2022

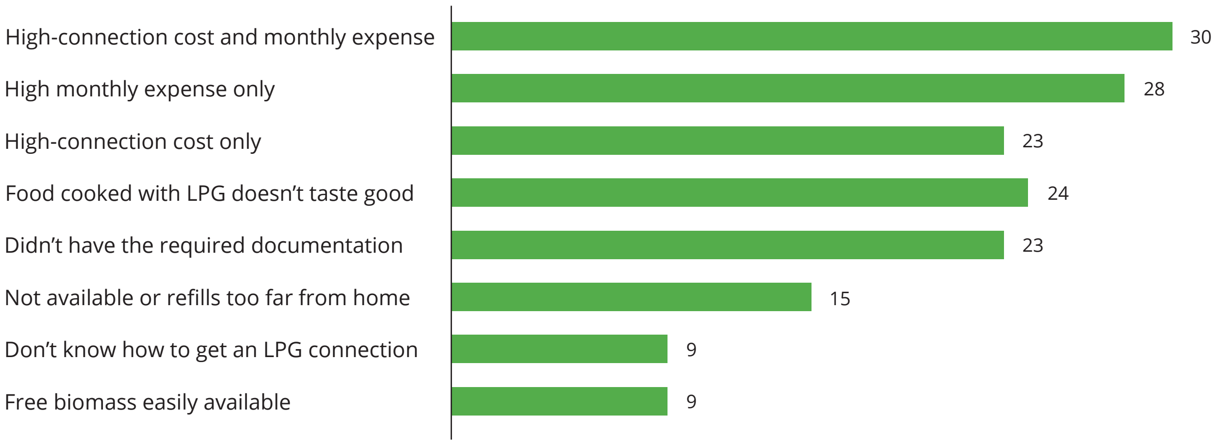
CHALLENGES IN OVERALL COVERAGE

Government efforts in the form of subsidies and promotion of clean cooking fuels have led to a rise in the number of households using LPG as their primary fuel. However, 84% of households continue to use traditional solid fuels along with LPG for cooking purposes. High cylinder cost is the main reason cited by most households that stack solid fuels with LPG. Other reasons for fuel stacking include a preference for cooking on traditional chulhas (72% of households), the availability of free biomass (59% of households), and the limited availability of LPG refills (46% of households). For the households without an LPG connection (15% of total households), the main reason for not having one remains high connection cost or the recurring expense of LPG refills.

A new LPG connection typically costs 3,200 rupees (around $44), and the LPG refill cost which has varied over a period of time.[18] Under PMUY, the government, subsidised only the LPG connection cost, and consumers had to pay the remaining amount either through a loan from an oil marketing company or cash. Both the initial and recurring expenses represent a substantial outlay for these households. Three-quarters of households without LPG connections earn less than 10,000 rupees per month and live in kutcha (temporary) or semi-kutcha houses. Further, most of these households rely on labour activities as their primary income source, thus making LPG unviable at current prices.

Exhibit-5.9: Reasons for not having an LPG connection

Share of household which use only solid fuel for cooking, *percent*



Source: Council on Energy, Environment and Water, State of clean cooking energy access in India: Insights from the India Residential Energy Survey (IRES) 2020, September 2021

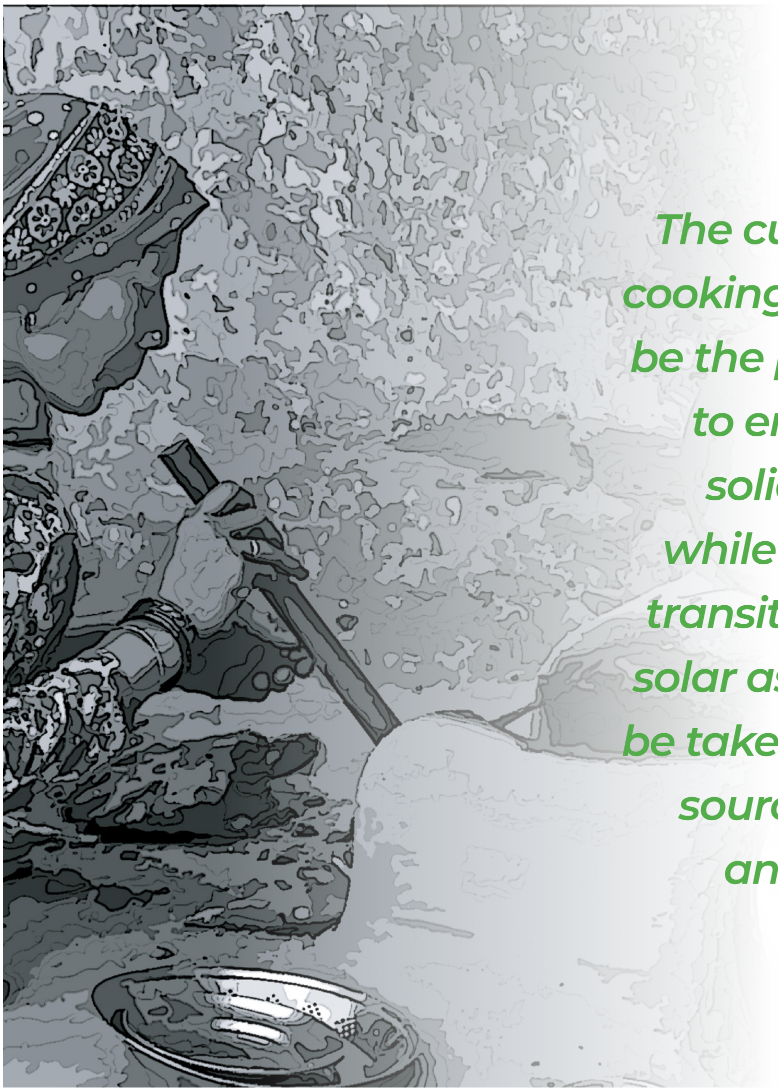
Even though, PMUY is aimed to simplify the enrollment process by reducing documentation requirement and introducing a quick application process through outreach camps[19], some households also highlighted the non-availability of LPG in their vicinity and easy availability of biomass as reasons for not having an LPG connection. Apart from the expense, some of the other reasons cited for not having an LPG connection include the taste of food cooked with LPG not being good or households not having required documentation. It is thus clear that, as India rolls out PMUY 2.0, there is an opportunity to identify and support more socio-economically marginalized households. Also, to sustain the use of LPG as the primary fuel, efforts to improve LPG access would need to be supplemented by incentives to make LPG consumption affordable. Beyond LPG, as the global push for decarbonization accelerates, it will be important for India to move to solar and electricity as options for cooking. This will, however, be a longer-term transition as India improves its electricity penetration and composition of renewables in grid.

[18] *Kumar, 2018*
[19] *Giri and Aadil, 2018*

POTENTIAL SOLUTIONS FOR TRANSITION TO CLEAN COOKING FUELS

Studies have highlighted that long-term health benefits can only be gained with sustained and universal use of clean cooking energy. Hence, there is a need to simultaneously emphasise and facilitate the sustained use of clean cooking fuel within households. Sustained use of clean cooking energy implies continued use of fuel as the primary cooking fuel without occasional relapses to traditional biomass. The current state of Indian cooking necessitates LPG to be the primary cooking fuel to ensure the move from solid fuels to clean fuels, while directional efforts to transition to electricity and solar as cooking fuels could be taken up such that these sources gain prominence and wider usage as we move forward.

While the complete transition to renewable sources of cooking fuel will take time, efforts need to be made to increase the use of LPG and PNG in households. There are several ways to increase LPG uptake in India. One solution is to incentivise rural distributors to improve home delivery of LPG by providing higher commissions per refill and linking the commission amount to connection density. Another is to connect LPG programs to broader social assistance or rural development programs. A third solution is to promote the production of biomass pellets and briquettes for commercial or industrial use to create new markets for biomass and nudge consumers toward adopting LPG for their cooking needs.



The current state of Indian cooking necessitates LPG to be the primary cooking fuel to ensure the move from solid fuels to clean fuels, while directional efforts to transition to electricity and solar as cooking fuels could be taken up such that these sources gain prominence and wider usage as we move forward.

Picture Credit: Adobe Stock

INITIATIVES TO SUPPORT TRANSITION TOWARDS CLEANER COOKING FUELS IN INDIA

1 Subsidizing up to eight LPG refills annually for domestic use

Before the discontinuation of LPG subsidies, households received subsidies for 12 LPG refills per year. According to the IRES, a typical household relying exclusively on LPG for cooking consumes around seven to eight refills per year. Limiting the annual subsidy to seven or eight LPG refills (as opposed to 12 refills) could reduce the subsidy bill by 13 to 15 %. These measures will also result in better targeting, as around three quarters of the LPG users, who consume more than seven refills annually, belong to the wealthier sections of society. Besides, movements like 'GiveItUp,' which could be termed hugely successful, could be used to encourage those who can afford to give up subsidies. This will also help bring down the subsidy burden.

2 Leveraging robust indicators to exclude households with high income or wealth status

In 2018, the Ministry of Petroleum and Natural Gas announced the exclusion of households with an annual income greater than 1 million rupees ($13,700) from the LPG subsidy. However, only 4.6 million households fall into this category, making up less than 2 % of Indian households (assuming one individual per household). A new categorization for eligibility for subsidy should be mandated to avoid inclusion errors.

3 Strengthening the LPG supply chain infrastructure

Another alternative would be to strengthen the LPG supply chain infrastructure and incentivize same-day home delivery, so that the households that stack because of poor availability of LPG reduce stacking and increase their LPG refill consumption. Adding home delivery infrastructure and the associated improvement in refill rate can also help job creation.

4 Using historic consumption data to provide differential subsidies

Households lower down on the economic ladder exhibit lower refill rates, all other things being equal. The administrative data on LPG refills could be used to study linkages between household LPG consumption behavior and LPG's affordability. This assessment could be used to target subsidies for consumers with low refill rates—a consumption linked approach. For instance, consumers with an annual consumption of up to three refills (in the past one to two years) could be given a higher subsidy per refill than those with a historical consumption of four to seven refills. It must be noted that any targeting measure would likely incentivize some households that would no longer be eligible for the subsidy to take up multiple LPG connections or exploit other loopholes in the targeting mechanism.

5 Electric/Solar Cooking

To transition at a rapid pace, Electric cooking needs to be promoted through campaigns. Wherever possible at least 50% of the cooking should be done through electricity. To further the net-zero ambitions, equipment like Solar stoves (Surya Nutan) and Concentrated Solar-Thermal Power (CSP) Cookers need to be adopted on a commercial stage.

6 Timely receipt of subsidy

Besides subsidy provision, ensuring timely subsidy receipt is also essential. Since 2015, the LPG subsidy was directly credited to consumers' registered bank accounts after every refill.[20] However, there have been instances of the subsidy getting transferred to the wrong account or receiving no subsidy.[21] Thus, it is crucial to monitor whether households are aware of and able to access the subsidy transferred to their accounts. With recent developments in the area of fin-tech and overall connectivity and advancement of technology, this should no longer be a significant hindrance.

7 Ease of availability of LPG

Apart from affordability, the limited availability of LPG refills is another key reason households cited for stacking LPG with solid fuels. Ease of LPG availability depends on factors such as access to home delivery, the travelling distance (and the associated economic implications) to procure an LPG cylinder (if there is no free delivery), and the time between placing the order and cylinder delivery. Given the significant increase in LPG dealerships and improvement in supply mechanism over the last few years, this might only be an issue of perception and hence could be sorted out through campaigns.

8 Target setting for promoting PNG

The demand for PNG in urban areas has primarily been driven by its convenience and lower recurring costs than LPG and electricity. However, the PNG's connection cost (5,000 rupees plus other charges) can limit its affordability among the lower economic strata, even in urban areas. Moreover, there are only about 80 Lakh PNG connections in India. The coverage of PNG needs to be expanded and a target of 3 Crore connections by 2030 needs to be set to boost PNG consumption

9 Clean fuel blending in LPG

Like the blending of Ethanol in Petrol, blending alternatives in LPG needs to be researched. DME blending in LPG has shown promise to provide a solution. Similarly, trials of Hydrogen blending in CGD are in progress. More R&D is needed to discover other substitutes to LPG that are derived from biomaterials available in India. Stoves working on biofuels like ethanol, methanol etc., need to be further developed and commercialized.

The objective of all the initiatives is to reduce the dependence of Cooking on LPG and promote cleaner cooking. India should target to reduce this dependence by 20% before 2030 and further improve by reducing it by a minimum of 50% by 2030.

[20] *Jain, Agrawal, and Ganesan, 2018*

[21] *The Hindu Business Line, 2018; Anbuselvan, 2019*

CONCLUSION

LPG penetration in India has reached a new high due to the Government's recent efforts, with more than 85% of households now with an LPG connection. However, more than 50% of these households still use some proportion of traditional solid fuels, primarily due to the relatively higher cost of LPG refills. These solid fuels are a leading cause of household air pollutants. Thus, access to clean cooking fuel is critical in achieving improved population health, along with the benefit of environmental protection.

Government programs such as PMUY have helped increase the penetration of LPG in India. However, due to the volatility in LPG market prices on account of global linkages and the subsidies on LPG being withdrawn, many households are shifting to using traditional cooking stoves. In the shorter term, better affordability and availability of LPG across the country is critical to ensure that LPG penetration in the usage of energy for cooking continues to stay high and gradually reaches close to 100%. To achieve this, it will be essential to implement targeted subsidies to only PMUY users and incentivize rural distributors to improve the home delivery of LPG. Meanwhile, CBG could be the bridging fuel for some parts of India, while local CBG based network could also be evaluated in villages with a concentrated population.

Over the next ten years, a large part of urban India will have PNG grids laid out on account of the build out that is happening after the awarding of GAs over the last few years. The speed of household connections may be accelerated to increase connections from 95.21L to cover at least 50% of urban households by 2030. In parallel, the electrification of cooking is a natural trend that has happened in several countries, especially in urban areas. This may be encouraged, as the share of renewables in the electricity mix increases, given that it will result in automatic decarbonization. Solar based cooking could also be a means to decarbonize but would only work effectively for mass cooking use cases.

Photo Credit: Adobe Stock

Chapter 6

HYDROGEN

In this section

INTRODUCTION TO HYDROGEN

Hydrogen was first identified as a distinct element by British scientist Henry Cavendish after he generated hydrogen by reacting zinc with hydrochloric acid in 1776. However, some work around hydrogen was done even as early as the 1500s. French chemist Antoine Lavoisier gave hydrogen its name, which was derived from the Greek words—"hydro" and "genes," meaning "water" and "born of." Since then, different scientists have worked on the usability of the element as a part of the energy system. In 1838, the fuel cell effect combining hydrogen and oxygen gases to produce water and an electric current, was discovered by the Swiss chemist Christian Friedrich Schoenbein.

In 1845, Sir William Grove, known as the "father of the fuel cell," unveiled a practical scale of hydrogen usage by creating a "gas battery."

Hydrogen is increasingly being seen not only as a potential solution to the predicaments of the present global energy system – mainly climate change and air pollution – but also as a means of scaling up ways of complementing other clean energy forms. At present, most globally produced hydrogen is used as chemical feedstock (Chemical usage) in refineries, fertilizers and methanol production. However, hydrogen has the potential to be used in other sectors as an energy carrier.

Exhibit-6.1: Use of hydrogen across various sectors

POWER	TRANSPORTATION	SPACE HEATING	INDUSTRY
Hydrogen can be used as a tool for daily and seasonal system balancing when power generated from renewables dwindles.	Hydrogen can be used in hydrogen fuel cell vehicles and even in internal combustion engines (ICE) as the fuel of the future.	Hydrogen can be used for domestic space heating purposes.	Hydrogen can be used as a feedstock for high-temperature applications that are essential for some industries to survive such as methanol and fertilizers.

Presently, hydrogen is primarily being used as feedstock in many industries. However, with technological advancements in electrolyzers (for green hydrogen) and developments in carbon capture and storage technology (CCS used for blue hydrogen), it is expected to be the clean fuel for the future, notably to be utilized by the many countries pledging for carbon neutrality and reducing emissions in line with the Paris Agreement. According to the recently held COP26 summit in Glasgow, hydrogen is integral to the global 2050 vision, with nearly 30 countries releasing hydrogen roadmaps.

The hydrogen economy is an important consideration for the Indian Government. In the budget speech of 2021, the finance minister launched the National Hydrogen Mission for generating hydrogen from green power sources.

Different color codes have been assigned to distinguish between hydrogen generated from various sources. "Black," "Grey," or "Brown" refers to the production of hydrogen from coal, natural gas/naphtha, and lignite, respectively. "Blue" is commonly used for hydrogen produced from fossil fuels with the capture of CO_2 generated in the process. Carbon emissions are reduced by utilizing carbon capture utilization and storage (CCUS) technology. "Green" is a term for hydrogen produced through water electrolysis using renewable electricity.

GREY HYDROGEN

Grey hydrogen is obtained from natural gas or naphtha through steam methane reforming (SMR) reaction. More than 76% of global hydrogen is produced this way. This is a mature technology and hydrogen obtained from this route is relatively cheap (~$2/kg), however large amounts of carbon dioxide emissions (10 times of hydrogen produced) are also associated with it.

BLUE HYDROGEN

Blue hydrogen is produced from fossil fuels capturing carbon emissions using Carbon Capture Technology, in which carbon dioxide emissions can be reduced by 85%. This type of production adds to the cost of hydrogen (~1.5 times), i.e., $80 to $120/ton of carbon dioxide. The transportation of captured carbon dioxide utilization adds complexity.

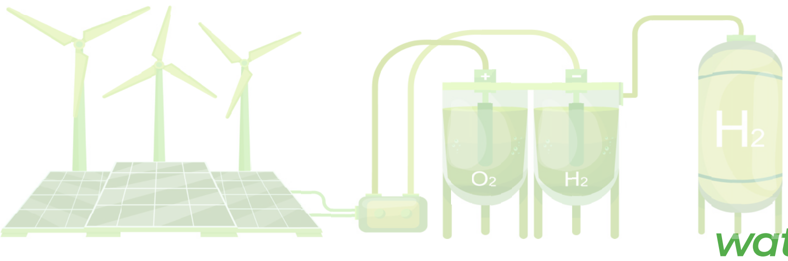
GREEN HYDROGEN

Green hydrogen is the zero-carbon production pathway. Water Electrolysis is done using renewable energy (solar / wind electricity) whereas bio-based technology is also prominent. It is currently expensive ($5 to $6/kg), however with rapid development in technology and bulk deployment through demand creation through policy interventions is expected to bring down the cost and the long-term forecast seems to be attractive ($1.5 to $2/kg).

Exhibit-6.2: Comparision of Green Hydrogen Policy of India and that of the United Nations Framework Convention on Climate Change (UNFCCC)

Indian Government	UNFCCC
▪ Green hydrogen can be manufactured by a developer using energy from a co-located renewable energy plant or sourced from a remotely located renewable energy plant, whether set up by the same developer or a third party, or procured from the power exchange. ▪ 25 years of free power transmission for any new renewable energy plants set up to supply power for green hydrogen production before July 2025. This means that a green hydrogen producer would be able to set up a solar power plant in Rajasthan to supply renewable energy to a green hydrogen plant in Assam and would not be required to pay any interstate transmission charges.	▪ 100% renewable energy will be defined as: renewable electricity supplied through a direct connection to the hydrogen production from a source of supply that comes into operation after or at the same time as the hydrogen production facilities. ▪ 100% renewable energy, provided the conditions to be laid down in the delegated acts are satisfied, will be defined as: electricity that has been transmitted through the grid where it can be shown that the other applicable sustainability criteria have been met (including temporal and geographical correlation of supply and demand) and that (as above) the relevant source of supply has come into operation after or at the same time as the hydrogen production facilities. ▪ Electricity taken from the national grid –the share of renewable energy in the relevant national grid as a whole – will be used to determine the share of such energy that will be considered renewable.

GREEN HYDROGEN PRODUCTION TECHNOLOGIES



Green Hydrogen is produced through water electrolysis using renewable power.

ALKALINE

It is a well-established technology. Advantages include relatively low cost, high durability and tolerance to impurities, highest-scale of green hydrogen production with lowest cost. Challenges include high lower limit of minimum load, high capital cost, threat of leakage and cross-over of gas. There are a few limitations related to current alkaline electrolyzer technology, namely, limited operational flexibility (although, this is improving), a larger area footprint, and low output pressure.

PEM

PEM electrolyzers have several advantages including the ability to scale output up and down rapidly, work above capacity for short periods, smaller footprint, and deliver hydrogen at a higher output pressure. Its advantages include a low level of partial load, a fast response for electrical grid balancing and several others. Challenges include the high cost of catalysts and electrodes, the corrosive nature of non-noble metal used as catalysts, and carbon monoxide poisoning.

SOLID OXIDE ELECTROLYSIS CELL (SOEC)

Uses solid ceramic material (such as Y_2O_3 doped ZrO_2) as electrolyte to combine electric current and water for hydrogen production, oxygen produced at anode is utilized to generate electrons for external circuit. SOEC technology is not commercially available and is the least mature. The process has relatively low material costs, but these materials face rapid degradation due to high operating temperatures (900 to 1,000°C), which results in high overall costs. Its advantages include extremely high efficiency, lowest level of minimum load, and its operability with inexpensive / stable catalysts. Its disadvantages include increased start-up / break-in times due to high temperature and low durability.

Table-6.1: Comparison of above three electrolyzer technologies

Attribute	Electrolyser Type		
	Alkaline	PEM Cell	SOEC
Status	Well Established	Established	Status Developing
Electrolyte	KOH / NaOH	Polymer	Y_2O_3 doped ZrO_2
Cell Temperature	60 to 80^{0}C	60 to 80^{0}C	60 to 80^{0}C
Stack Pressure	< 30 bar	< 30 bar	-
Cell Voltage Efficiency	52 to 69%	57 to 69%	-
System Lifetime	20 to 30 years	10 to 20 years	-

ANION

To overcome challenges of an alkaline electrolytic environment, polymer technologies such as anion exchange membrane (AEM) are currently being developed. AEM electrolyzers use an alkaline solution of lower concentration, thereby making them less prone to corrosion. Advantages include the prevention of potential electrolyte and gas leakages, the high efficiency and purity of the hydrogen generated, and its use of inexpensive catalysts. Its disadvantages include the high lower limit of minimum load, lower water splitting than PEM, the decreasing ion conductivity of the membrane, and its extreme sensitivity to carbon dioxide affecting performance.

HYDROGEN FROM BIOGAS

Similar to the steam reforming of natural gas/naphtha, hydrogen can also be produced from renewable biogas. Biogas can be produced by the anaerobic digestion of various organic matters, such as municipal solid waste, food waste, animal manure, sewage, crops, and agricultural residues. Biogas contains methane in the range of 50 to 70% with 30 to 50% carbon dioxide and minor quantities of nitrogen, particulates, and other contaminants that complicate the gas cleanup processing. Hydrogen sulfide, siloxanes, and halogens are the most damaging impurities that need to be removed to sub-ppm levels, and this adds to the cost of cleanup. Therefore, an additional biogas cleanup step is required for the removal of carbon dioxide, sulfur, and other impurities before converting biogas into hydrogen. Once the biogas has been upgraded to natural gas quality biomethane or bio-CNG (compressed natural gas), it can be used as a substitute for natural gas in the SMR process to produce hydrogen. Plants for production of biomethane from organic waste are usually located close to points of feedstock production. Hence, biomethane-based hydrogen production is well suited for decentralized hydrogen production, thereby overcoming the challenges associated with hydrogen transportation and storage (classified as blue or grey, depending on technology used for biogas clean-up step). However, major technical barriers for converting biogas to hydrogen are like those found in the conversion of natural gas using a SMR process. Furthermore, the requirement of preconditions and the cleanup of biogas before reforming constitute an additional set of challenges for the widespread application of hydrogen production from biogas. In addition, the transportation and distribution systems for bio-methane have not yet been established, which add to the cost of hydrogen production.

Exhibit-6.3: Production cost* of green hydrogen worldwide by country in 2020

The cost of hydrogen produced from electrolysis today is relatively high, at around Rs 400/kg versus Rs 140 to 180/kg from natural gas reformation. Capex requirements today are in the range of $500 to $1,400/kilowatt electric (kWe) for alkaline electrolyzers and $1,100 to $1,800/kWe for PEM electrolyzers, while estimates for SOEC electrolyzers range close to $2,800 to $5,600/kWe.

Country	2020 min	2020 max	Country	2020 min	2020 max
Argentina	4.25	4.50	Morocco	4.25	4.50
Australia	4.50	4.75	Poland	5.00	5.25
Brazil	4.50	4.75	Russia	3.75	4.00
Canada	3.75	4.00	Saudi Arabia	4.25	4.50
Chile	3.50	3.75	South Africa	4.25	4.50
China	4.00	4.25	South Korea	6.25	6.50
France	4.25	4.50	Spain	4.75	5.00
Germany	4.75	5.00	Sweden	7.25	7.50
India	4.25	4.50	United Kingdom	3.75	4.00
Japan	6.25	6.50	United States	4.25	4.50

** The above prices are in euros per kilogram.*

Source: https://www.statista.com/statistics/1086695/green-hydrogen-cost-development-by-country/

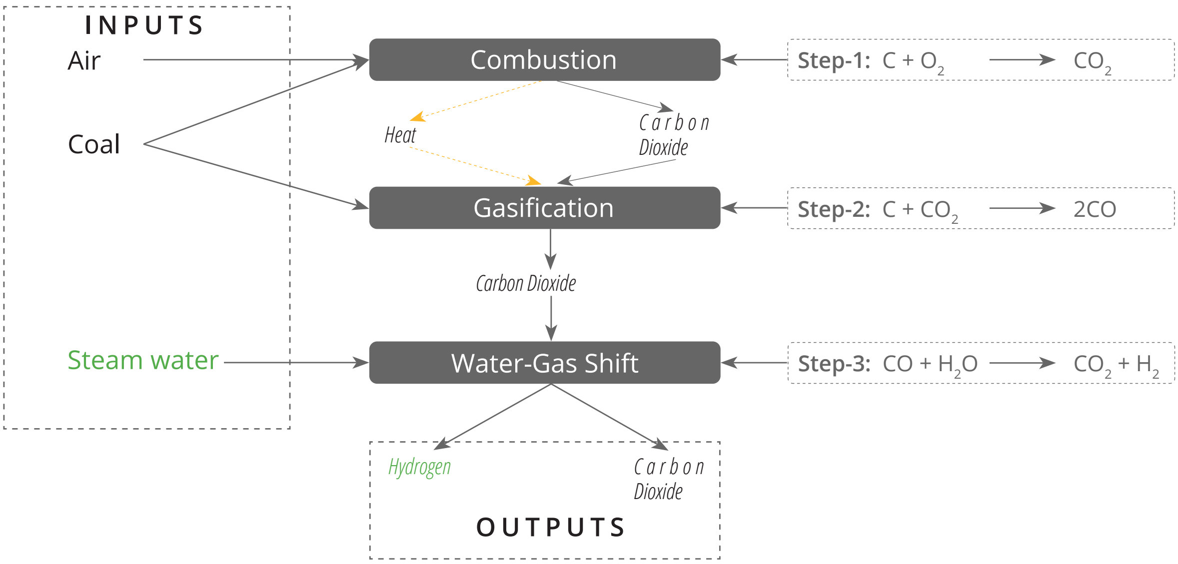
PHOTOLYSIS

Solar energy is a promising source of energy as it is inexhaustible, clean, and environment-friendly. Solar energy can be used for renewable hydrogen without any greenhouse gas (GHG) emissions. Concentrated solar power (CSP) technologies are presented as solutions with high economical and technical potential for hydrogen production. The heat generated from CSP, also referred to as solar thermochemical (STCH), can be used for high temperature thermochemical splitting of water into hydrogen and oxygen. Chemicals used in this process are reused within each cycle, creating a closed loop that consumes only water and produces hydrogen and oxygen. This is a long-term technology pathway and calls for producing hydrogen in semi central and central facilities. Several solar thermochemical water splitting cycles have been assessed for hydrogen production, each with different sets of operating conditions, engineering challenges, and hydrogen production opportunities. More than 300 water splitting cycles have been reported in the literature.

STCH is a promising technology for the clean, sustainable production of hydrogen in large quantities. Current R&D priorities focus on materials development for the reactive material as well as the reactor material and design. STCH processes are divided into direct cycles that only use concentrated solar thermal energy and hybrid cycles, which additionally use an electricity-driven electrolysis step as part of the water splitting cycle. Direct thermal cycles have a lower complexity but require higher operating temperatures, whereas hybrid cycles operate at relatively lower temperatures and offer practical advantages in reactor design and durability.

COAL-TO-HYDROGEN

Exhibit-6.4: Producing hydrogen from coal



BIOMASS GASIFICATION

Biomass gasification is a thermochemical conversion of biomass into synthesis gas (syngas). Syngas is a mixture of carbon monoxide, hydrogen, methane, and carbon dioxide, and heavier hydrocarbons such as tars. The gasification process can potentially convert all organic matter, including lignin, present in biomass to syngas. Syngas is a very versatile product as it can be used for numerous applications such as the production of heat, power, transport fuels, hydrogen, and chemicals. Air-blown biomass gasification is a mature technology with many operating demonstration plants around the globe. However, the cleaning of syngas generated in biomass gasification for removal of impurities still involves many operational problems due to the presence of large quantities of tars.

Exhibit-6.5: Pathway for hydrogen production from biomass

1 Air-blown Biomass Gasification

In air-blown biomass gasification, biomass reacts with air in a gasifier operating at high temperatures (>700°C) to generate syngas. Generated syngas is subjected to rigorous gas cleaning process to remove carbon/char particulates, tars, and nitrogen- and sulfur-based compounds, trace metals, etc. Purified syngas from a gas cleaning system is admitted into a water gas shift (WGS) reactor to convert the carbon monoxide present in syngas to hydrogen and carbon dioxide by reacting with steam. Hydrogen-rich syngas leaving the WGS reactor is admitted to a hydrogen separation/purification system to separate the hydrogen from the other gaseous mixture. Different gasifier configurations such as downdraft, updraft, and fluidized bed reactors are commonly used for the gasification of biomass.

Air-blown biomass gasification has been widely used for power generation. However, air-blown biomass-gasification based hydrogen generation is associated with various challenges such as the presence of large quantities of nitrogen and heavier hydrocarbons in syngas, a lower hydrogen yield, a variation of syngas quality with biomass feed type, and removal of all syngas impurities.

2 Oxy-steam Biomass Gasification

Air-blown biomass gasification generates quite low hydrogen yield per kg of biomass compared to its theoretical potential. Oxy-steam biomass gasification is a promising technology for the production of hydrogen, economically using indigenous biomass-based feed stocks. Oxy-steam-biomass-gasification-based hydrogen production involves the oxy-steam gasification process for syngas generation followed by a syngas cooling and conditioning/cleaning system coupled with a hydrogen separation system for generating hydrogen. The hydrogen yield and hydrogen-to-carbon monoxide ratio in the syngas generated from oxy-steam biomass gasification depends on the equivalence ratio (ER) and steam-to-biomass ratio (SBR). The maximum achievable hydrogen yield in oxy-steam biomass gasification process per kg of biomass is 104 g. Various biomass resources such as wood, agricultural residues, briquettes, and consumer wastes can be processed in oxy-steam biomass gasification.

Though oxy-steam biomass gasification process looks promising for low-cost hydrogen, the technology has not yet been demonstrated at higher plant capacities. Indian Institute of Science (IISc), Bangalore has developed a novel oxy-steam biomass gasification process & developed proof of concept to generate hydrogen-rich syngas. The institute has demonstrated a hydrogen production plant at 2 kg/h scale on its campus. IISc & Indian Oil Corporation Ltd. signed an agreement to optimize the developed process and aim to demonstrate oxy-steam-biomass-gasification-based hydrogen production technology at 10 kg/h scale

SUPPLY CHAIN OF HYDROGEN

Step-1 Production

Type of Hydrogen Produced

- Grey
- Turquoise
- Green
- Blue & Blue+
- Yellow
- White

In India, most hydrogen is produced via natural gas for use in the refinery and fertilizer industries. Different colour coding has been given to production routes in addition to grey (natural gas based), blue (fossil fuel with CCUS technology), and green (renewable energy based) hydrogen. Turquoise hydrogen is the hydrogen obtained from pyrolysis, yellow is obtained from electrolysis with mixed-origin grid energy as feedstock, whereas naturally occurring hydrogen is considered white hydrogen.

Step-2 Storage

Type of Storage

- Compressed
- Liquefied
- Metal & Chemical Hydrides

Hydrogen can be stored physically as a gas or liquid. The storage of hydrogen as a gas in vehicles requires high pressure (~350 to 700 bar) due to space constraints but can be stored at lower pressures for stationary applications (~100 bar). Storage as a liquid requires cryogenic temperatures (-253˚C) (BNEF, 2019). The appropriate storage medium depends on the volume, storage duration, required discharge speed, and the geographic availability of different options (IEA, 2019).

Table-6.2: Hydrogen Storage

Technology	Year	Unit	Cost	Description
Salt Cavern Storage	2020	Rs. / kg of H_2	3.7	Salt Cavern Storage (20% vol.)
	2050		1.5	Salt Cavern Storage (20% vol.)
Rock Cavern Storage	2020		10.4	Rock Cavern Storage (20% vol.)
	2050		3.7	Rock Cavern Storage (20% vol.)
Steel Tank	2020		48.1	700 kg capacity
	2050		40.0	1,100 kg capacity

Source: The Potential Role of Hydrogen in India, TERI,2020

Step-3

Compression

Type of Compression

- Diaphragm
- Ionic
- Cryogenic
- Electrochemical

Hydrogen not only needs to be produced, but also transported and stored close to the place of consumption. Such activities are challenging due to the characteristics of hydrogen. It is flammable, it has low density, and is easily dispersed into the air. The easiest and most economical way to store and use hydrogen is in the form of compressed gas at a pressure of 200 to 250 bar (and over). Recently, remarkable progress has been made by introducing metal structure tanks and thermoplastic structure tanks reinforced with carbon fiber, glass fiber, and other materials, whose weight is one third to one fourth of common tanks.

Step-4

Transportation

Type of Transportation systems

- Trailers
- Pipelines
- LOHC
- Methanol & Ammonia

The low energy density of hydrogen means that it can be costly to transport over long distances. Nonetheless, several possible options are available to overcome this hurdle, including compression, liquefaction, or incorporation of hydrogen into larger molecules that can be more readily transported as liquids. New infrastructure could also be developed, with dedicated pipeline and shipping networks potentially allowing large scale overseas hydrogen transportation.

Table-6.3: Hydrogen Transport

Technology	Year	Unit	Cost	Description
Transmission Pipeline	2020	Rs. / kg of H_2	2.2	50 km distance, 1000 tpd
	2050		1.5	50 km distance, 1000 tpd
Distribution Pipeline	2020		6.7	50 km distance, 100 tpd
	2050		5.2	50 km distance, 100 tpd
Truck	2020		11.8	50 km distance, 700 kg capacity
	2050		40.0	50 km distance, 200 kg capacity

1 MTPA steel plant approx. 150 tpd

Refuelling station upto 1 tpd

Source: The Potential Role of Hydrogen in India, TERI,2020

... contd. from previous page

Step-4

Transportation

... contd. from previous page

Models for Hydrogen Production & Transport in India

- On-site, distributed production model for co-located users
- Production hub and grid model (similar to the current natural gas infrastructure)

Ammonia is an important route to carry hydrogen – starting with obtaining hydrogen from water, nitrogen from air, and using green electrons for electrolysis to split water into oxygen & hydrogen. The same energy can power the separation technology to obtain pure nitrogen from air. Once nitrogen & hydrogen are produced, Haber-Bosch process can be used to produce ammonia.

Ammonia contains 18% H_2 by weight, requires no cooling and is more efficient to transport & store, making it an efficient hydrogen carrier. Among common & stable molecules, only methane has more hydrogen content (20%). Liquid hydrogen, is fairly dense, requiring extensive cooling and special storage in robust tanks. Gaseous hydrogen (100% pure) lacks density, making it ineffective.

Step-5

Applications

Type of Applications

- Stationary
- Mobile
- Process

The industrial sector is currently the dominant user of hydrogen both in India and globally. Most of the globally produced hydrogen is currently utilized in four sectors: fertilizers, refineries, petrochemicals, and methanol. There are also several new sources of hydrogen demand in previously untapped industries. The main sector of interest is iron and steel, where hydrogen has the potential to replace coking coal, non-coking coal, and natural gas, depending on production route.

Beyond the steel sector, there is also the potential for hydrogen to replace fossil fuels as a source of industrial heat:

- **Chemical** – ammonia, polymers, and resins
- **Refining** – hydrocracking and hydrotreating
- **Iron and steel** – annealing, blanketing gas, and forming gas
- **General industry** – semiconductor, propellant fuel, glass production, hydrogenation of fats, and cooling of generators

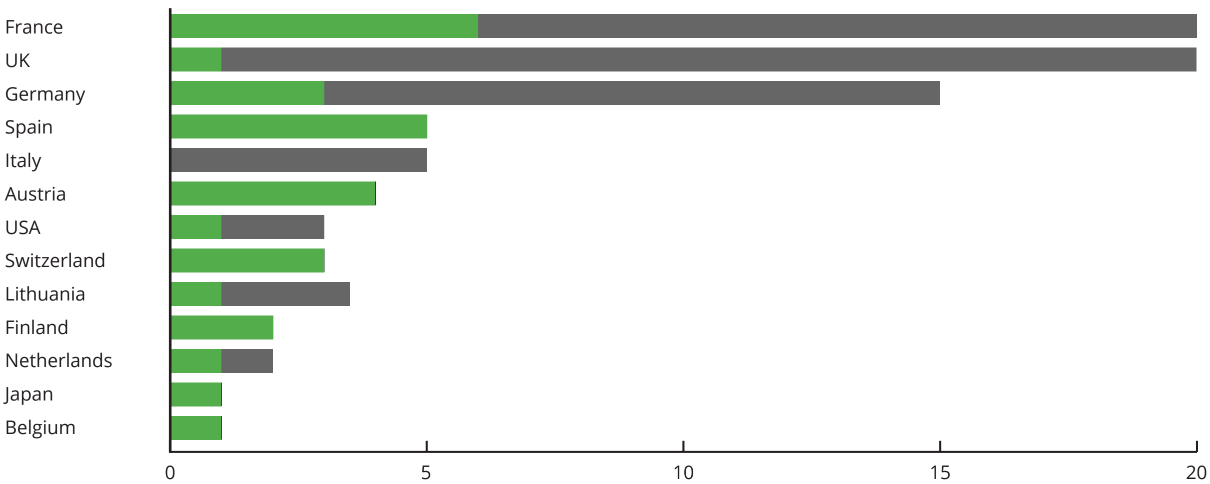
BLENDING HYDROGEN IN CGD PIPELINE

Many countries have started injecting hydrogen (low percentage by volume) in the natural gas pipeline network. Natural gas pipelines are considered a long-distance transportation option for hydrogen extraction at PR stations, bringing down the cost. CBG pipelines are being set up under the Sustainable Alternative Towards Affordable Transportation (SATAT) program for various gases, which, subject to some further investigation could become potential carriers of hydrogen. Studies are being carried out to understand the impact of hydrogen transportation on pipeline metallurgy.

In January 2022, GAIL Limited started India's maiden project of blending hydrogen into the natural gas system in Indore – supplying 2% hydrogen blended (by volume) natural gas via 1,100 kms Avantika Gas pipeline network. Oil India has also taken up similar project in Assam.

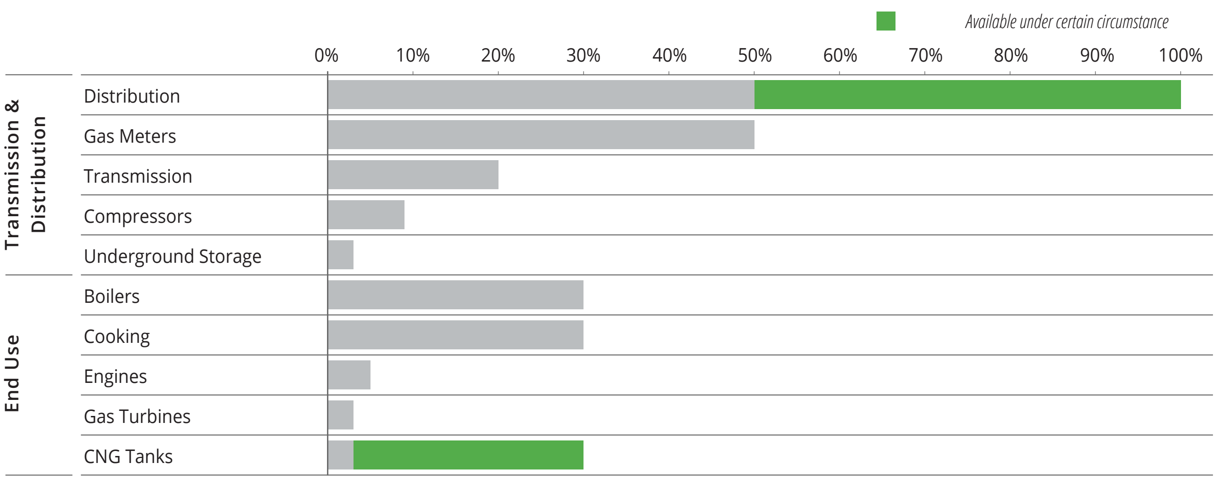
Green hydrogen can be blended in natural gas networks, substituting imported natural gas and reducing end-use carbon emissions. It is estimated that blending 1% hydrogen by volume would substitute about 0.3% of natural gas demand.

Exhibit-6.6: Regulatory Blend Walls for Hydrogen, % hydrogen by volume



Source: S&P Global Platts Analytics, HvLaw

Exhibit-6.7: Tolerance of existing components for hydrogen blending in Natural Gas



Source:

Altfeld and Pinchbeck (2013), "Admissible hydrogen concentrations in natural gas systems," Gas Energy http://www.gasfor-energy.com/products/2013-admissible-hydrogen-concentrations-in-natural-gas-systems-1/; Jones, Kobos and Borns (2018), "Geologic storage of hydrogen: Scaling up to meet city transportation demands," Inter. Journal of Hydrogen Energy; Kouchachvili and Entchev (2018), "Power to gas and H2/NG blend in SMART energy networks concept", Renewable Energy; Melaina, Antonia and Penev (2013), "Blending hydrogen into natural gas pipeline networks: A review of key issues," National Renewable Energy Laboratory; Müller-Syring and Henel (2014), "Wasserstofftoleranz der Erdgasinfrastruktur inklusive aller assoziierten Anlagen," DVGW; Reitenbach, et al. (2015), "Influence of added hydrogen on underground gas storage: a review of key issues," Environmental Earth Science; Weidner et al. (2016), "Sector Forum Energy Management/Working Group Hydrogen Final Report."

GLOBAL AND DOMESTIC HYDROGEN DEMAND AND SUPPLY

Globally, ~94 MMT (Million Ton) of hydrogen is used in different processes annually; 73 MT is used for refining, ammonia making, and other pure uses, while about 21 MT is used for methanol, steel making, and other mixed uses.

Exhibit-6.8: Build-up of hydrogen usage for refining, Ammonia making and other pure uses

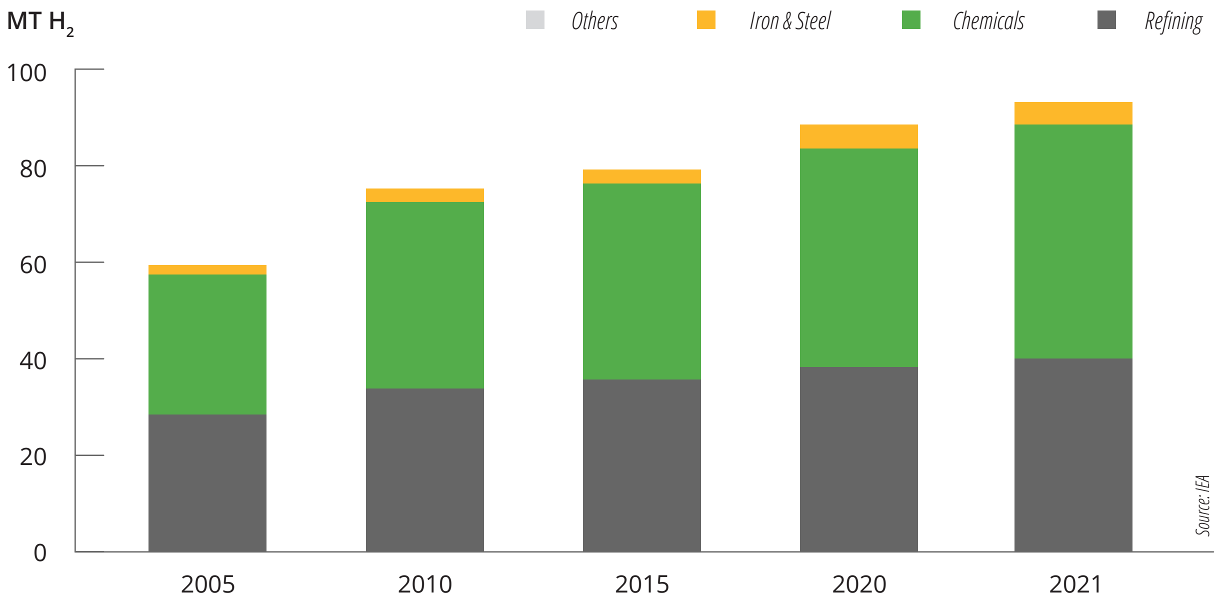
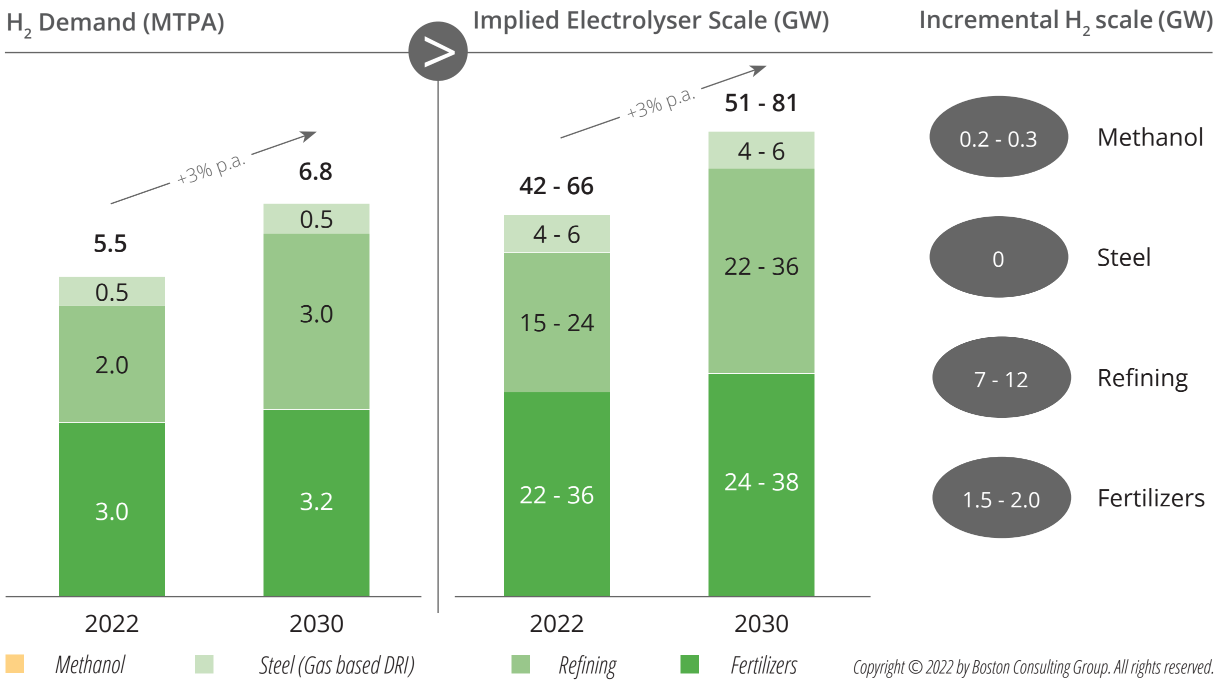


Exhibit-6.9: Trends in the Indian hydrogen demand



HYDROGEN USAGE IN REFINERY, FERTILIZER & METHANOL

99%

Of pure hydrogen demand in India comes from primarily two sectors, i.e. refinery & fertilizers

Almost all hydrogen in refinery & fertilizer units is produced through the SMR process using natural gas or naphtha.

- Grey hydrogen consumes approximately three times the amount of fossil fuels per unit of hydrogen production
- SMR process releases approximately ten times the carbon dioxide per unit of hydrogen produced

Petroleum Refining

Photo Credit: Adobe Stock

Usage of Hydrogen in Petroleum Refining

1 Hydrotreating of petroleum fuel to meet fuel specifications, primarily desulphurization and for blending with MS and HSD (methanol and ethanol).

2 Hydrocracking of heavier petroleum feedstock into a lighter and more valuable product

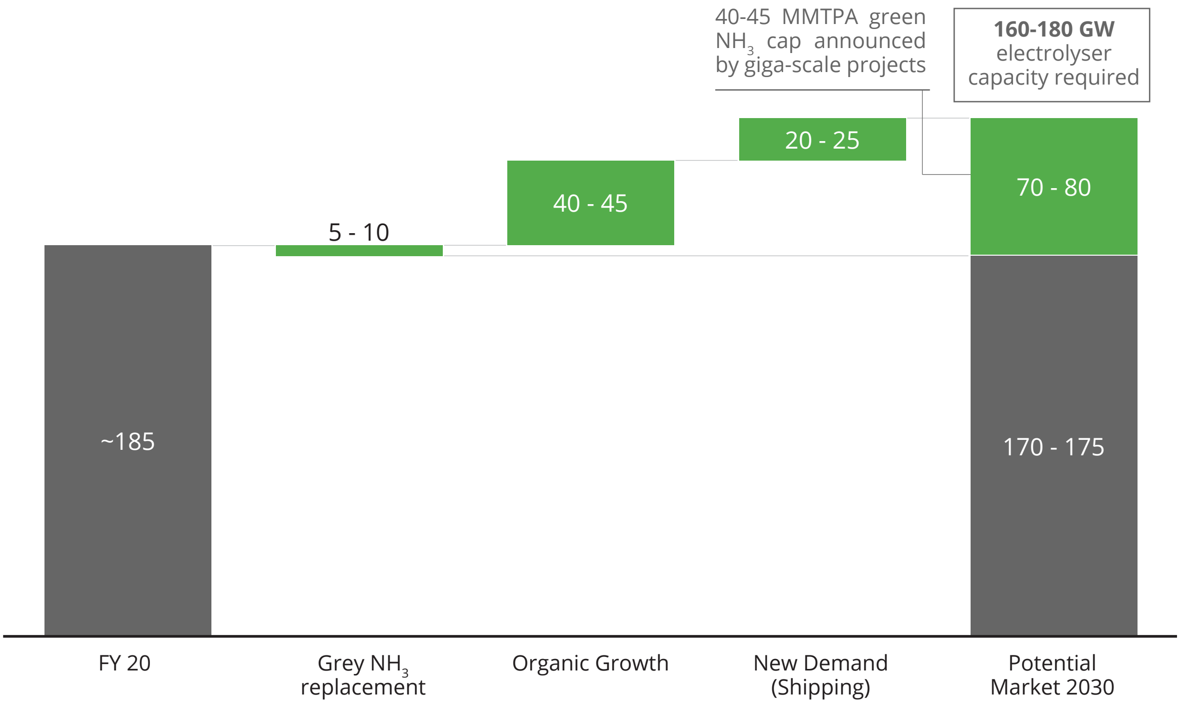
The level of hydrogen consumption in oil refineries is dependent on several factors, including the density of the crude oil; the sulfur ratio of the crude oil; the complexity of the refining operations and the quantum of bottom-of-the-barrel refining; the product slate of the refinery; and the emission norms applicable at the end-user level. The Indian refining sector uses ~2.1 MMTPA of hydrogen. Out of the total refinery hydrogen consumption, part of the hydrogen gets produced as a by-product of the catalytic reforming process (~15%), depending on the refinery configuration. The rest of the hydrogen is primarily produced from SMR and the WGS of fossil fuels. In most cases, hydrogen is produced on site for captive consumption, with the typical hydrogen consumption of a refinery being ~1% of the refining capacity.

Fertilizer Industry

India consumes 3.1 MMTPA of hydrogen to produce ~15 MMTPA of ammonia. Hydrogen is used in production of ammonia for urea and di-ammonium phosphate (DAP). Ammonia is used to produce urea and non-urea fertilizer like DAP.

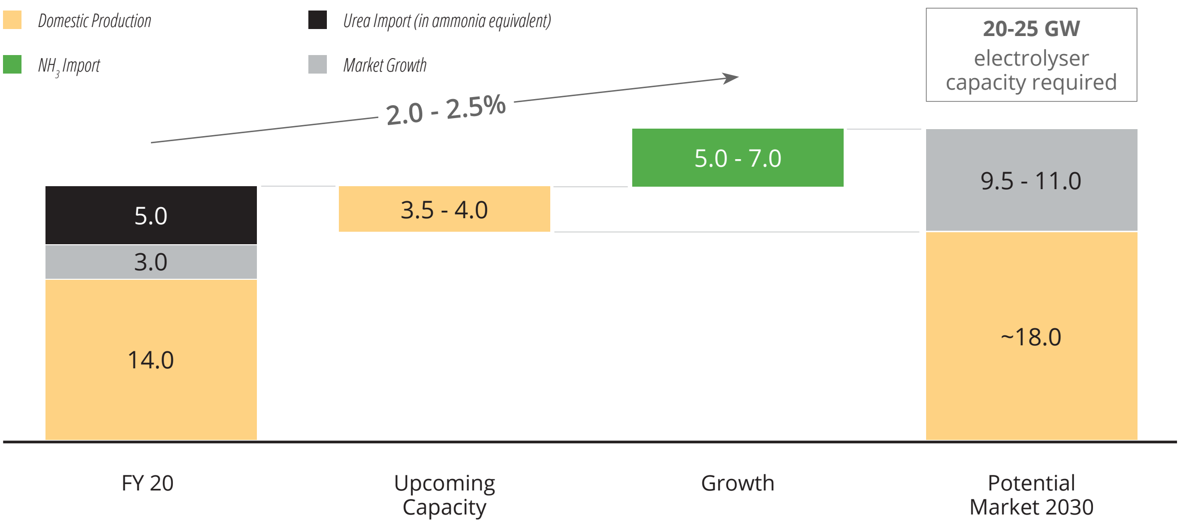
- Hydrogen consumption in urea production is ~0.1 kg per kg of urea
- Hydrogen consumption in DAP production is ~0.035 kg per kg of DAP

Exhibit-6.10: Global Ammonia Market (in MMTPA)



Source: IEA, Kearney Energy Transition Institute, Kearney analysis

Exhibit-6.11: Indian Ammonia Market (in MMTPA)

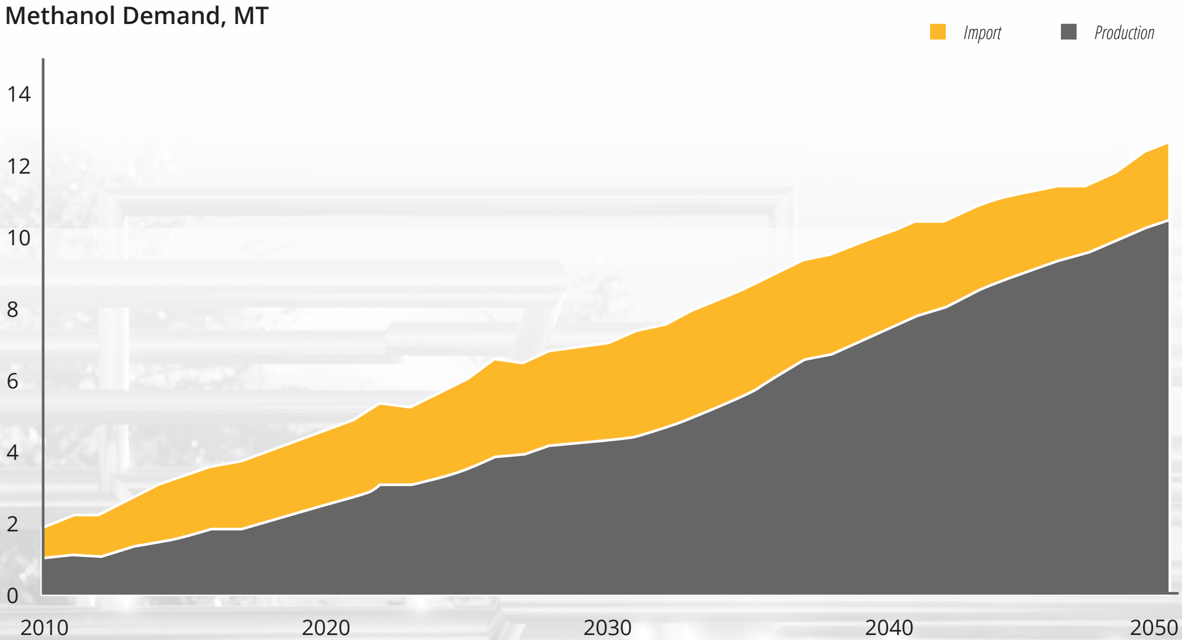


Source: IEA, Kearney Energy Transition Institute, Kearney analysis

Methanol Industry

The methanol industry in India is relatively small, with a demand of around 2.26 MT in fiscal year 2021, and a forecast is 4.01 MT by the fiscal year 2030. The average price of natural gas used in methanol production in the Middle East is ~$2 to $3/MMBtu (Metric Million British Thermal Unit), versus the historical average of imported price of natural gas of ~$10/MMBtu for India.

Exhibit-6.12: Methanol Demand - domestic production & import, 2020-2050



Source: TERI analysis based on (Ministry of Chemicals and Fertilizers, 2029)

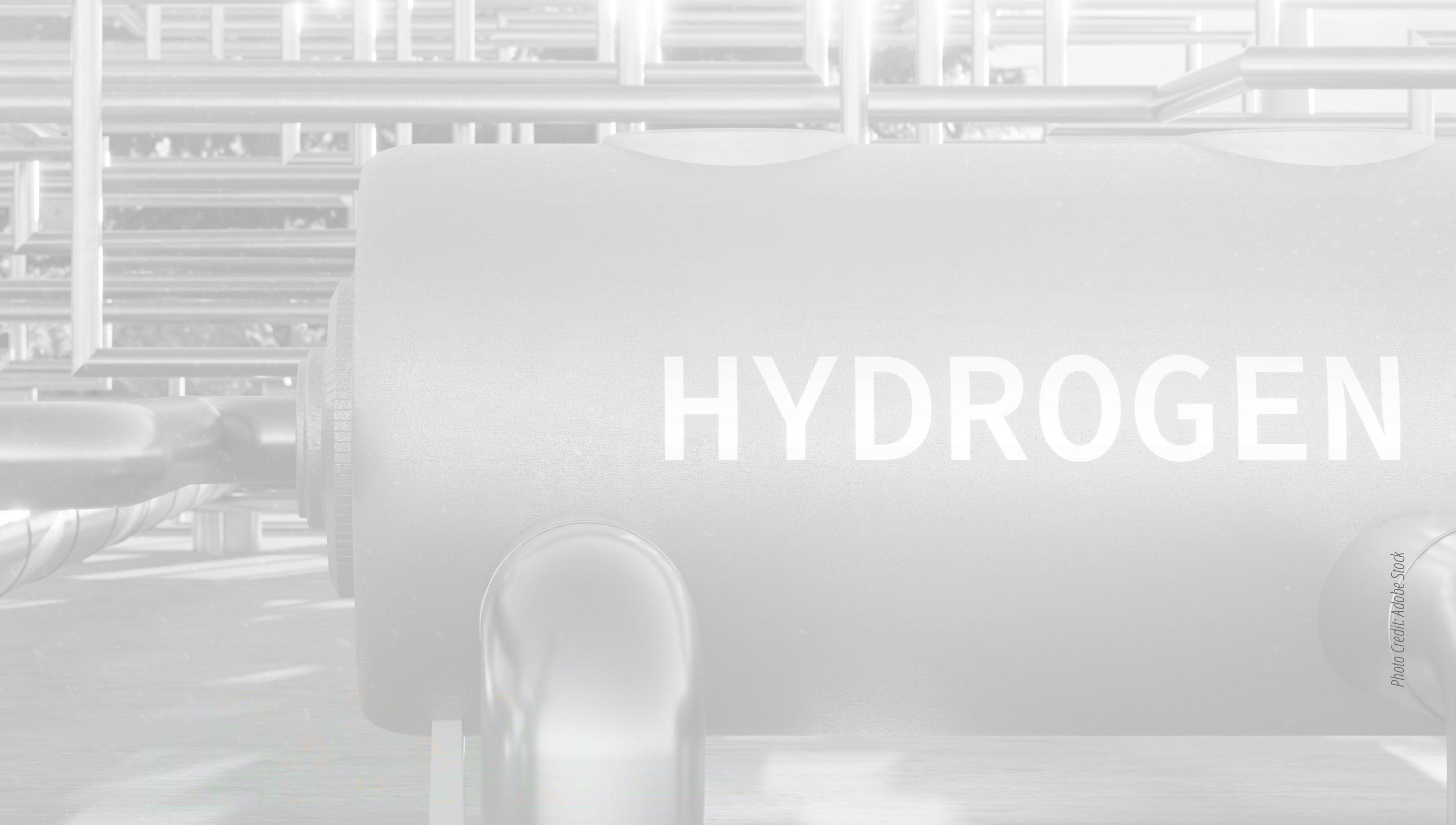
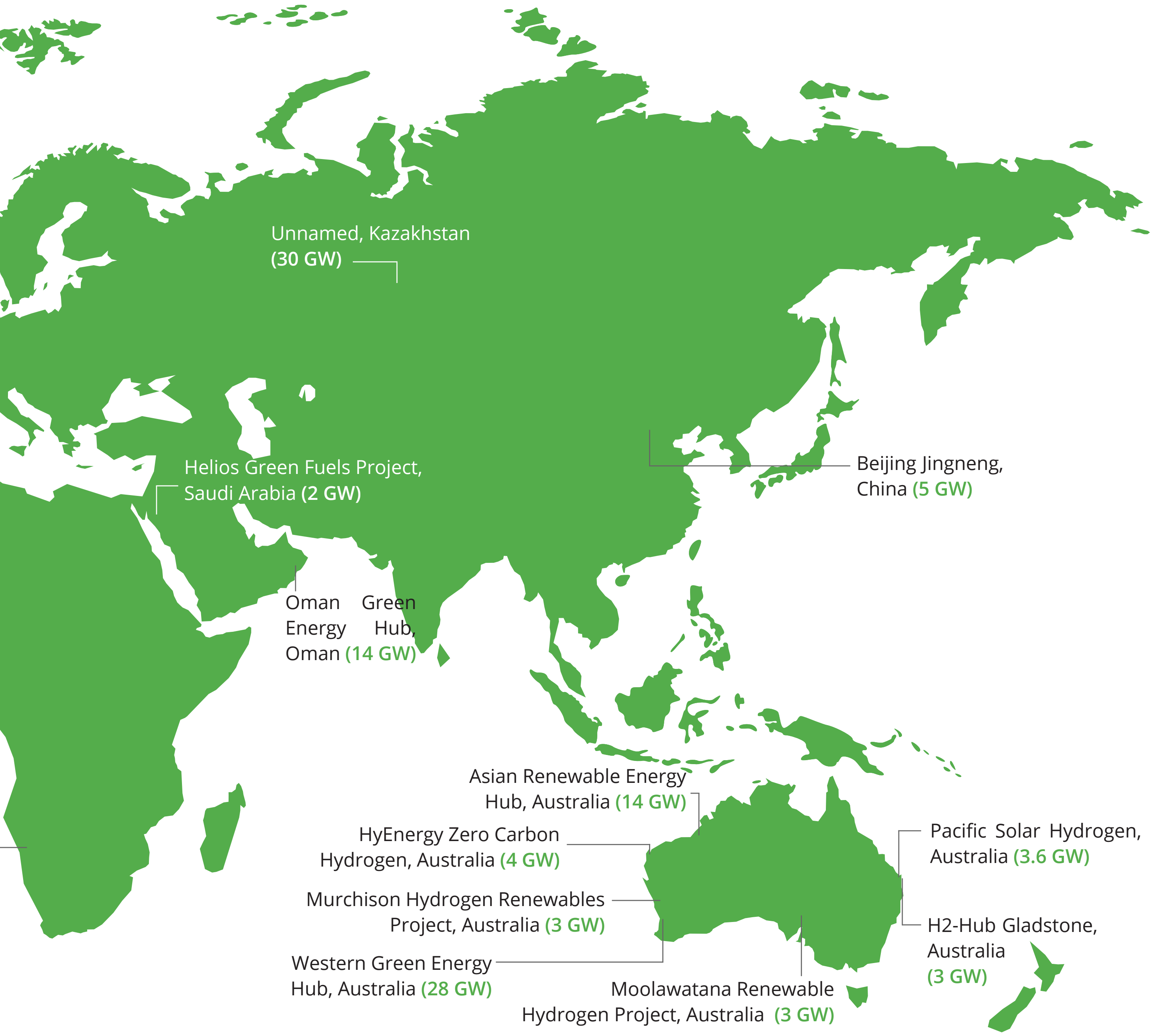


Photo Credit: Adobe Stock

MAJOR GREEN HYDROGEN PROJECTS (GLOBAL)


Unnamed, Kazakhstan
(30 GW)
Helios Green Fuels Project,
Saudi Arabia (2 GW)
Beijing Jingneng,
China (5 GW)
Oman Green
Energy Hub,
Oman (14 GW)
Asian Renewable Energy
Hub, Australia (14 GW)
HyEnergy Zero Carbon
Hydrogen, Australia (4 GW)
Murchison Hydrogen Renewables
Project, Australia (3 GW)
Western Green Energy
Hub, Australia (28 GW)
Moolawatana Renewable
Hydrogen Project, Australia (3 GW)
Pacific Solar Hydrogen,
Australia (3.6 GW)
H2-Hub Gladstone,
Australia
(3 GW)

CHALLENGES IN SCALING-UP GREEN HYDROGEN MARKET

1

Cost

The cost of clean hydrogen, particularly green hydrogen, is still high relative to high-carbon fuels. Not only the cost of production but the costs of transporting, converting, and storing hydrogen are also high. Adopting clean hydrogen technologies for end uses can be expensive, and CCS is yet to be deployed at scale.

2

Technology Maturity

Some technologies required for decarbonization in the hydrogen value chain still have a low level of technological readiness and need to be proven at scale. For instance, gas turbines that operate exclusively with hydrogen are unavailable off the shelf. When it comes to maritime trade, only one prototype vessel can transport liquid hydrogen.

3

Efficiency

Hydrogen production and conversion involve significant energy losses at each stage of the value chain, including production, transportation, modification, and use. Moreover, the production of blue hydrogen is energy-intensive, adding to the overall energy demand and thus becoming costlier.

4

Renewable electricity availability

By 2050, hydrogen production with electrolyzers may consume close to 21 000 TWh (600-650 mn MT of H2 production equivalent)– almost as much electricity as is produced globally today (IRENA, 2021a). As more end-use sectors are electrified, a lack of sufficient renewable electricity may become a bottleneck for green hydrogen.

5

Policy / Regulatory uncertainity

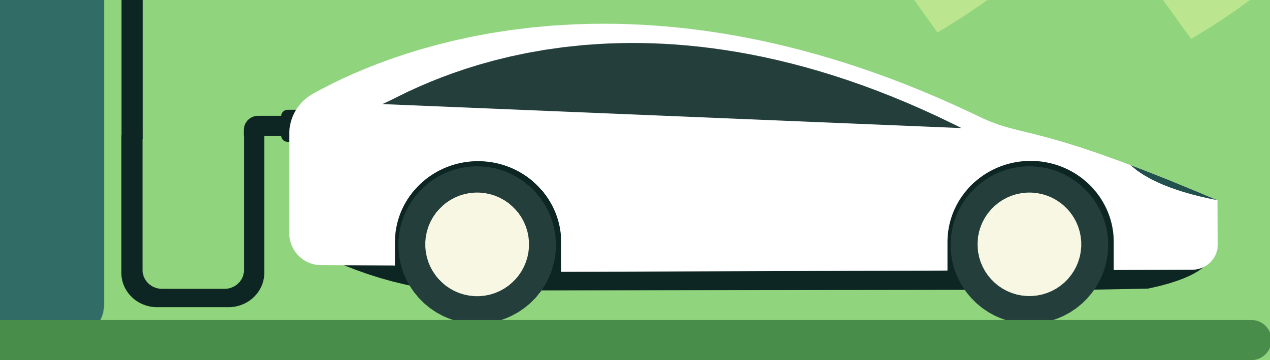
Although over 140 countries have pledged to achieve net-zero emissions within the coming decades, the speed with which these goals will be achieved remains uncertain. Stable, long-term policy frameworks are needed to support development and deployment at scale.

6

Standards & Certification

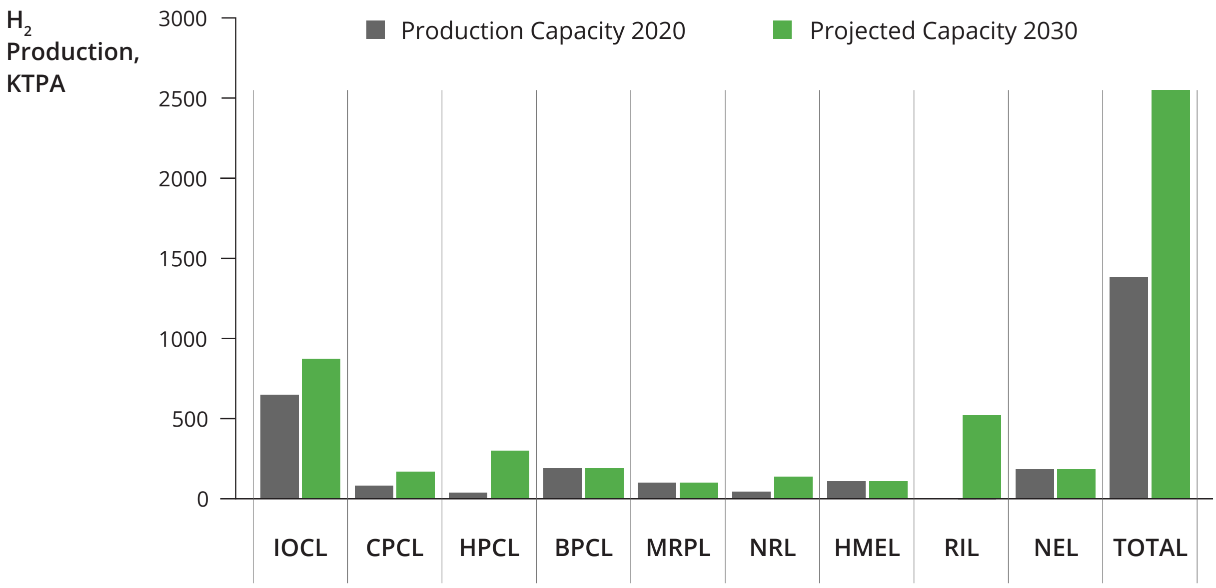
Countries lack institutionalized mechanisms to track the production and consumption of any shade of hydrogen and identify its characteristics (e.g., origin and life-cycle emissions) (IRENA, 2020b; IRENA, IEA, and REN21, 2020). Moreover, hydrogen is not counted in official statistics of the total energy consumption, and the economic value of clean hydrogen's contribution to emission reductions is not recognized.

There is a chicken-and-egg problem in building the necessary infrastructure for hydrogen. Without demand, investments remain too risky for wide-scale production that could reduce costs, but the technology remains too costly without economies of scale.



GREEN HYDROGEN POTENTIAL IN INDIAN O&G COMPANIES

Exhibit-6.13: Hydrogen production in Indian refineries (hydrogen generation units)



	IOCL	CPCL	HPCL	BPCL	MRPL	NRL	HMEL	RIL	NEL	TOTAL
Production Capacity (2020)	476	80	37	191	99	45	110	0	185	**1,406**
Projected Capacity (2030)	825	171	302	191	99	140	110	529	185	**2,593**

Source: MoP&NG; MNRE

Table-6.4: Indian O&G sector Green Hydrogen Plans

Organisation	Project Site	Green Hydrogen Capacity (kTA), 2024-25	Electrolyser Capacity (MW), 2024-25
IOCL	Mathura & Panipat Refineries	5	40
		2	16
HPCL	Visakh & Barmer Refineries	12.2	85
		4.3	30
BPCL	Bina Refinery	2.6	20
	Gaseous Hydrogen for H-CNG	0.63	5
GAIL	Hydrogen Blending in Pipeline	6.5	50
	Electrolyzer in Vijaipur	1.4	10
MRPL	Mangalore Refinery & Petrochemicals Limited	0.5	3
NRL	Numaligarh, Assam (2025-26)	3	20
Total		**38**	**279 MW**

Source: Oil Marketing Companies

Table-6.5: Electrolyser Technology Providers

Organisation	Electrolyser Type	Remark
Ohmium International	PEM	India's first Green Hydrogen Electrolyser Gigafactory. Capacity: 0.5 GW / Year
Nel Hydrogen	Alkaline & PEM	Different series with varying hydrogen production rates
Linde	PEM	...
Haldor Topsoe	SOEC	...
ThyssenKrupp	Alkaline Water Electrolysis	Standard Module of 20 MW
H2Pro	Membrane free E-TAC	...
Enapter	AEM	...
Siemens	PEM	Model Silyzer 300 (rating 17.5 MW per full module array (24 modules) - hydrogen capacity 335 kg / hr per full module
Cummins Inc.	Alkaline & PEM	...
Elogen	PEM	Modular, upto 10 MW
Green H2 Systems	PEM	1 to 100 MW
Giner ELX, Inc.	PEM	...
Green Hydrogen Systems	Alkaline	20 MW

Source: E4 Tech, 2019

IMPROVING POLICIES & ENABLERS TO BOOST GREEN HYDROGEN IN INDIA

- Facilitate access to low-cost renewable electricity
- Allow hydrogen mixed with natural gas to be used in existing natural gas infrastructure (as per safety regulations) by defining a remuneration mechanism to encourage renewable hydrogen injection into gas networks
- Develop appropriate mechanisms to price the emissions of GHGs, which would encourage decarbonization of the economy
- Partial exemptions of grid charges, taxes, and levies for electrolyzers
- Production-linked-incentive schemes for different components in green hydrogen or ammonia value chain:
  - Solar modules (announced)
  - Glass, EVA, and steel
  - Electrolyzers
  - Sea water desalination
  - Hydrogen & ammonia storage

Government has taken significant steps to create a transition ecosystem with a key role played by Hydrogen. It is desirable that the progress against the plans is monitored actively & any impediments shall be addressed immediately.

CONCLUSION

Despite being one of the earliest discovered elements and being recognized by scientists for its promise for applications in energy, hydrogen is yet to live up to the occasional promise exhibited by it. Once again, there is a lot of discussion around hydrogen being one of the major solutions as an energy source for transitioning toward net zero. It is hoped that necessary conditions are created this time around and green hydrogen will play a dominant role in the transition journey. Given the history, it is imperative that necessary conditions for transitioning towards a thriving hydrogen economy through gradual build up supported by an enabling framework of policies and global coordinated sharing of knowledge and technologies are created. It is quite likely that initially the most cost effective and pragmatic approach to scale up hydrogen usage could be insitu production and consumption of hydrogen through co-located production and consuming plants. Ongoing experiments about mixing hydrogen with piped gas could be another area, along with the use of hydrogen fuel cells for mobility to eventually build up towards wider usage of hydrogen across the spectrum. Given the highly cost intensive nature of current pathways, reserving a part of green financing for advancements in hydrogen technologies and applications must be considered.

We have looked at various types of hydrogen based on the production methods available, along with the multiple use cases where it can be used. Green hydrogen, which uses renewable energy as the raw material, is the most viable option for India to move towards a net carbon zero aspiration. Alkaline electrolyzers and PEM are the most commonly used processes to produce green hydrogen today, requiring a capex of $500 - $1800 /KWe and having a current price in the range of US$3.75 to $5.25 across various countries.

Transportation and storage are the key elements in the hydrogen supply chain that require extreme temperatures and pressure to make it viable. Potential exists to use the current city gas distribution pipeline. However, studies are being carried out to understand the impact of hydrogen transportation on pipeline metallurgy.

Globally 115 MT (megatons) of hydrogen is being used in different processes - 73 MT is used for refining, ammonia making, and other pure uses, while about 42 MT is used for methanol, steelmaking, and other mixed uses. In India, pure hydrogen is primarily consumed in two sectors, namely refineries and fertilizers (~99% of total demand). Currently, the Indian refining sector uses ~2.1 MMTPA of hydrogen, and the ammonia sector uses ~3.1 MMTPA of hydrogen.

~20 green hydrogen projects exist or have been announced across the world with a combined capacity of ~230 GW. The challenges for scaling up the green hydrogen market include cost, technology maturity, efficiency, renewable electricity and regulatory uncertainty. However, policies and enablers such as access to low cost renewable electricity, allowing hydrogen to be mixed with natural gas, developing appropriate mechanisms to price the emissions of GHGs, partial exemptions of grid charges, taxes, and levies for electrolyzers and Production Linked Incentive schemes (potentially similar to those provided for PV solar) for different components can help boost green hydrogen demand.

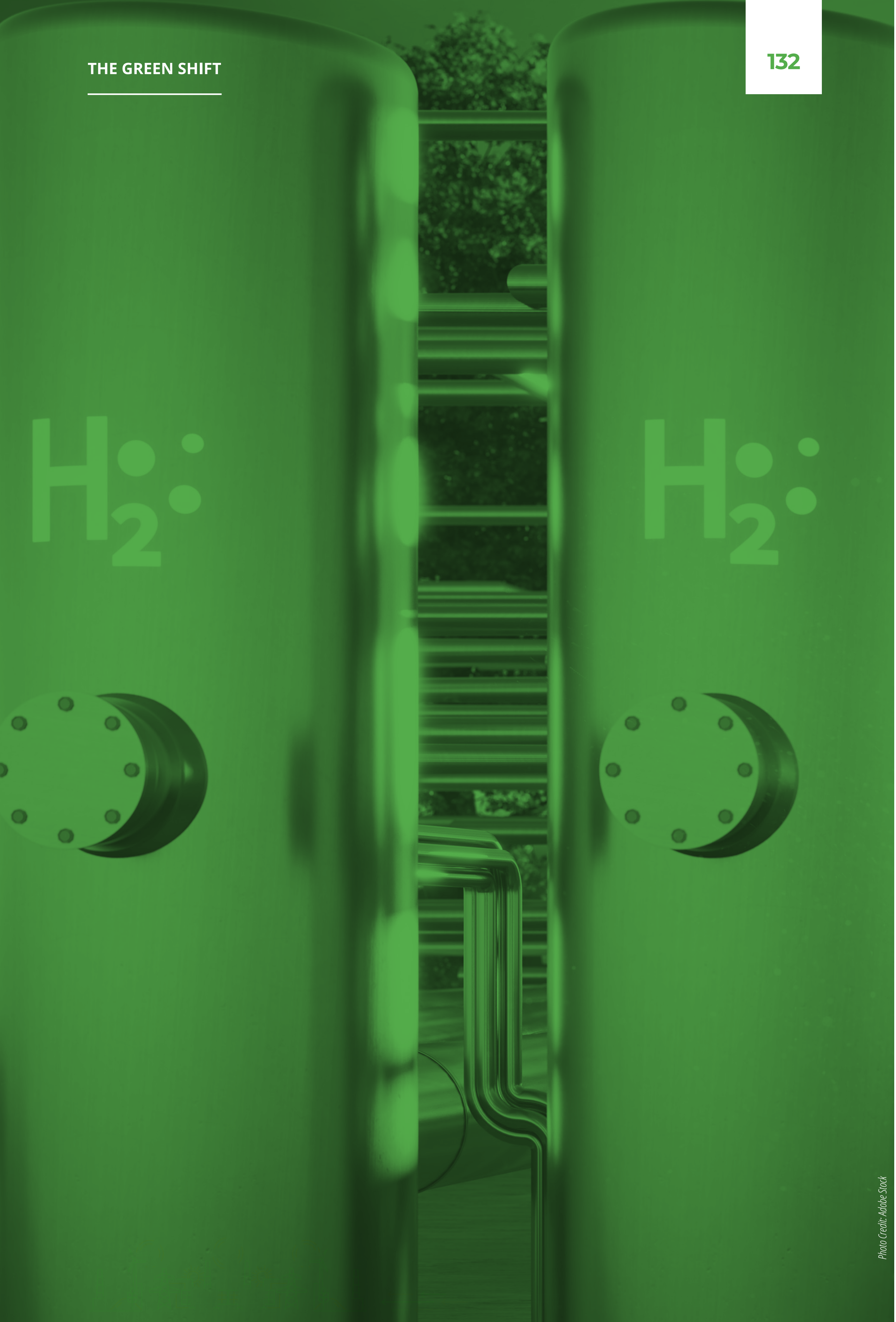


Photo Credit: Adobe Stock

Chapter 7

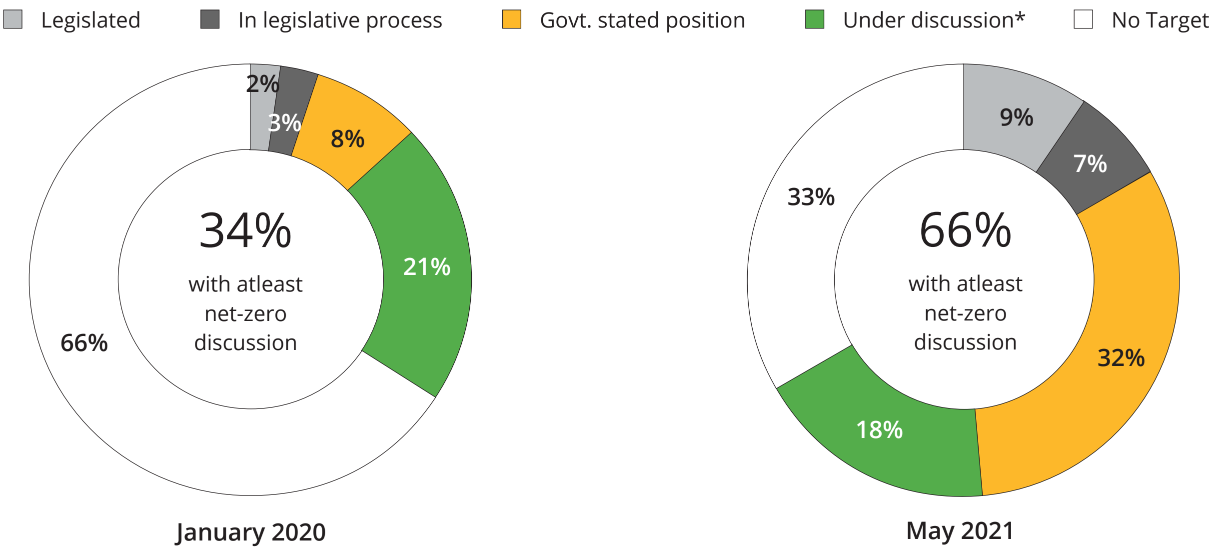
ENERGY OPTIONS AND ROADMAP FOR SURFACE TRANSPORT

In this section

GLOBAL OVERVIEW

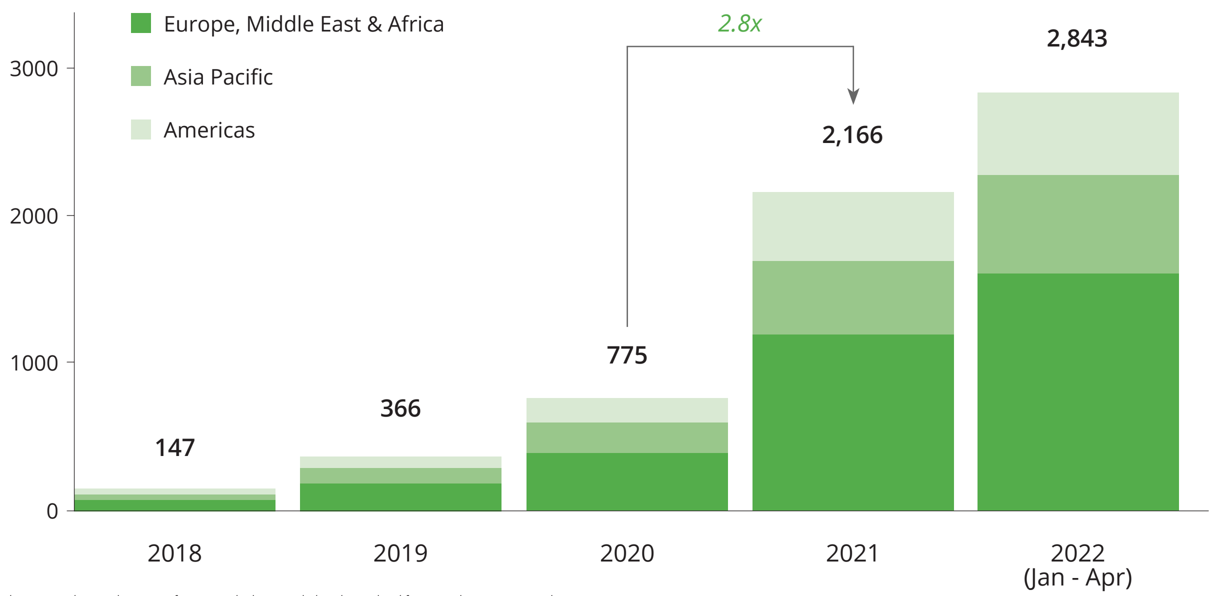
The transport sector and the mobility it affords is a crucial driver of any economy and a significant catalyst for development. This is even more evident in an increasingly global economy, where economic opportunities are closely linked to the mobility of people and freight. With the global economy growing at an unprecedented pace over the last few decades, the transport sector has also been expanding rapidly. However, this growth has resulted in several negative externalities, especially climate change.[1] With more and more Governments and business entities recognizing energy transition as core to future growth trajectory as evidenced by growing commitments, the issues relating to mobility and associated emissions have assumed special significance.

Exhibit-7.1: Growing focus on Net Zero



** "Under discussion" stage occurs when governments have begun concrete official discussions to implement a target.*

Source: Bloomberg NEF



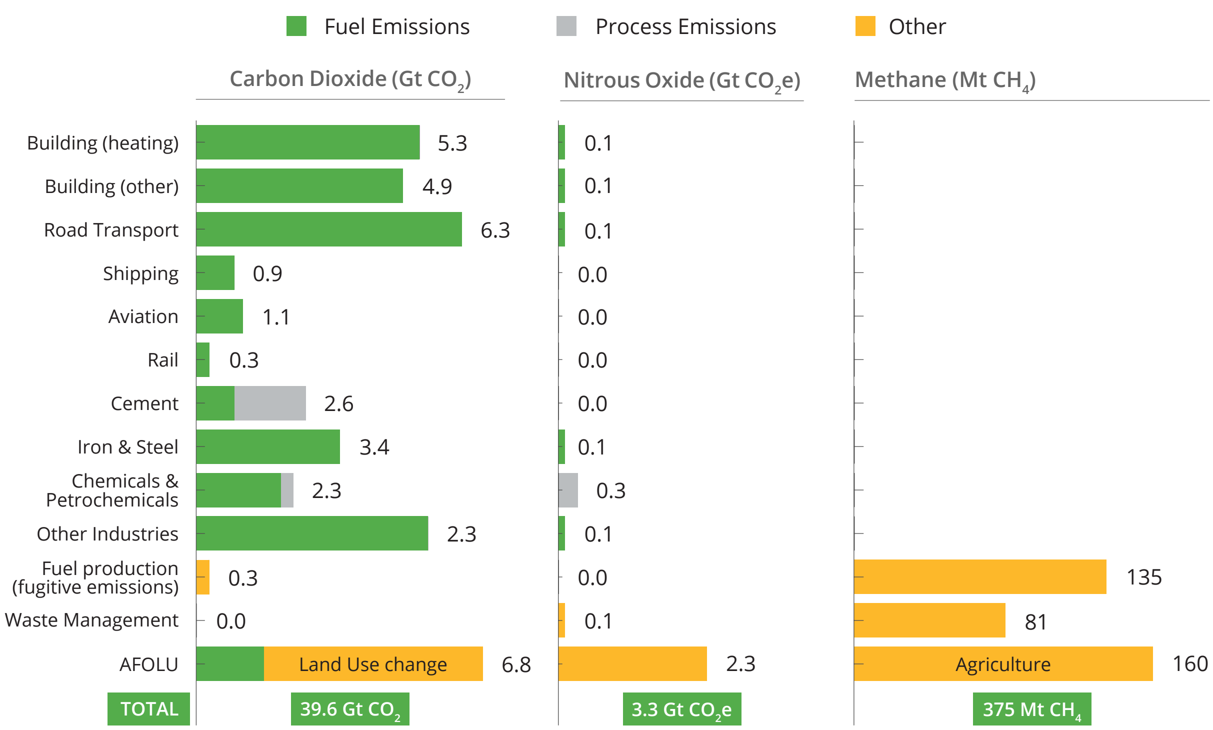
The COP 26 climate change conference took place in Edinburgh, Scotland from October 13 to November 12 2021

Source: CDP, Science Based Target Initiative; Bain Analysis

[1] https://www.teriin.org/sites/default/files/files/Decarbonization_of_Transport%20Sector_in_India.pdf

As the transport sector accounts for nearly a quarter of energy consumption in the world, decarbonization of the transport sector will play a critical role in energy transition and climate change mitigation[2]. The role of transportation was well recognized at COP26 in Glasgow, Scotland, where governments and businesses demonstrated a strong commitment to addressing the climate emergency. 197 countries signed the Glasgow Climate Pact, formalizing their commitments and pledges to net zero targets[3]. The number of companies pursuing science based decarbonization targets has nearly quadrupled since 2020.[3] Leaders from nations, cities, international organizations, NGOs, and notably the private sector zeroed in on the role of transport as one of three critical sources of carbon emissions and the only sector still increasing in its greenhouse gas (GHG) footprint. In 2020, the global transport industry was responsible for approximately 7.3 billion metric tons of carbon dioxide (CO_2) emissions.[4] The total energy use in the transport sector is responsible for 25% of direct carbon dioxide (CO_2) emissions from fuel combustion. Transport also depends on oil more than any other sector, as more than 90% of the energy use still comes from petroleum products. Without more ambitious policies, the global demand for passenger travel and the movement of goods is expected to more than double from 2020 to 2050, leading to an expected 16% growth in CO_2 emissions by 2050. Improvements in fuel and vehicle efficiencies are not advancing fast enough to reduce overall emissions as mechanized mobility demand is increasing due to population and GDP growth. Reducing transport CO_2 emissions is critical to meet the overall emission reduction targets and the goals of the net zero target pledged by various countries and economies[5].

Exhibit-7.2: Scope of emissions considered by sector (2020)



[2] https://www.sciencedirect.com/science/article/pii/B9780128159651000028

[3] As per the IPCC's definition of "net zero", in IPCC, Annex I: Glossary, in Global Warming of 1.5°C, op. cit.

[4] IEA

[5] https://www.energy-transitions.org/wp-content/uploads/2022/04/Mind-the-Gap-How-Carbon-Dioxide-Removals-Must-Complement-Deep-Decarbonisation-to-Keep-1.5C-Alive-1.pdf

Road transport currently accounts for nearly three quarters of transport CO_2 emissions. Up to 2020, however, emissions from aviation and shipping were growing faster. Emissions are projected to grow over the next few decades. Depending on post Covid-19 full recovery trends, this projection may change. Further, the transformation of global value chains and political concerns about high import dependency may bring changes to intercontinental shipping. Similarly, holiday patterns may vary, as may some business travel, as the world shifts to rely more on virtual meetings. No matter how post-Covid developments impact transport demand, there is still an urgent need to transform the sector to improve mobility, especially in developing countries, and at the same time reduce energy consumption and associated emissions of CO_2 and other air pollutants.

The electrification of private transport is showing signs of disruptive transition — global sales of electric cars in 2020 grew by 43% compared to 2019, reaching 3.2 million units and accounting for 4.2% of global new car sales. Key enabling technologies, such as battery packs and cells for mobility applications, saw rapid cost reductions from an average of USD 181/kWh in 2018 to USD 137/kWh in 2020 (the lowest-cost applications were under USD 100/kWh). At the same time, the use of electric two-wheelers and public transport is increasing as alternatives to private cars. It is important to underline that electrification of transport needs to be closely linked to renewable energy expansion and growth in the charging infrastructure.

A transformation will require sustained policy moves by all countries to address the challenges faced by different parts of the sector.

An interesting option to explore is how the growing pool of vehicle batteries might provide important, short-term storage flexibility to the power system. ***Electrification using presently available technologies is not currently a scalable option for heavy-duty transport, shipping, and aviation.*** This may change with innovation, but in the short term, ***there is a focus on increased use of sustainable biofuels and clean hydrogen in these sectors.*** Beyond the direct energy consumption associated with the transport service provided, there needs to be consideration of how broader life-cycle issues can be integrated into planning and policy. Several options are available for reducing both direct and indirect energy use.

Many of these are gaining increased interest, such as making vehicles with less or lighter material, increasing the recycling of different material components, and extending the total lifetime of vehicles. How relevant different elements will be for transport sector transformation in each country, depends on national circumstances.

GLOBAL APPROACH

Transforming the transport sector is an important part of the overall energy sector transition. The current high dependence on fossil fuels in the sector needs to be reduced quickly to make it part of an overall net-zero GHG emissions path.

Governments need to establish a transport sector plan of action as part of an integrated energy-sector transformation strategy, engaging actors at both national & local / city level, private sector, civil society, and others. From the outset, such a process needs to establish and be based on mid- & long-term targets aligned with national sustainable development plan and net-zero goals. It is important to analyse the pathways for reaching the targets and identifying the requirements for success. An implementation plan should include requirement for policy & institutional development, enhancement of labour skills, and finance & infrastructure needs.

Governments need to adopt a comprehensive "avoid-shift-improve" approach, where reducing demand, changing transport modes and improving the energy efficiency of mobility are considered in an integrated manner.

1 AVOID

Managing travel demand can be done in many direct and indirect ways. Options include infrastructure design, such as building higher density cities and local integration of workspaces and domestic dwellings. Pricing in different forms is also essential, including taxes on vehicles, fuels and parking, road use levies, freight handling charges in harbours and departure and arrival taxation in airports.

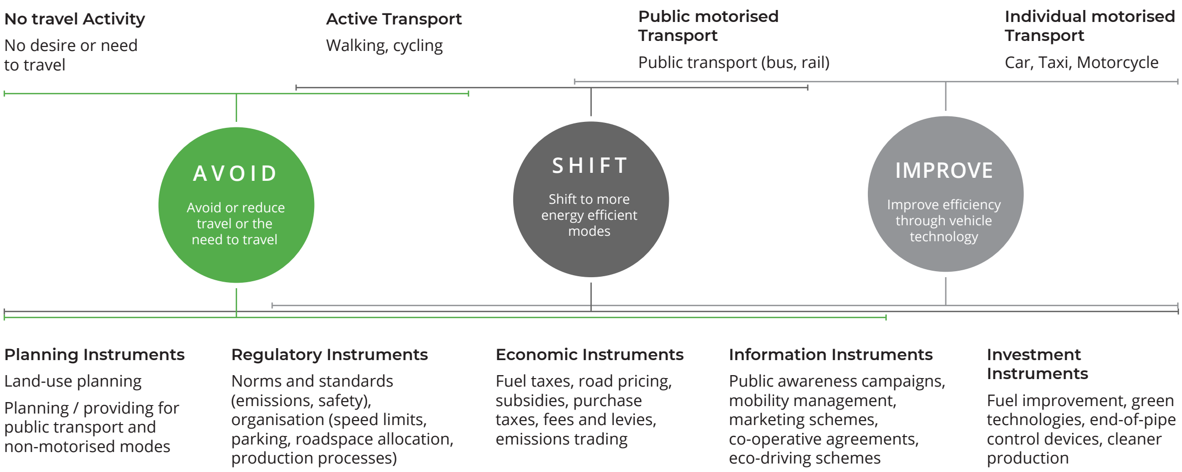
2 SHIFT

Stimulating use of the least energy-intensive modes of transport by, for example, creating favourable conditions for pedestrians, building bike lanes, and strengthening public transport and car-pooling choices through subsidies, and constructing fast track lanes in congested places. Integration of different transport modes benefits end users and enhances system efficiency. Electrification of both private and urban public transport, where possible, and creating fast electric train connections between major cities is another option.

3 IMPROVE

Increasing energy efficiency of vehicles & motorized two-wheelers through design, engine improvements, efficient air conditioners, and use of more efficient electrical motors. For land & sea freight and aviation, , where electrification is not relevant, exploring & promoting use of modern biofuels, hydrogen, or ammonia will be critical. Policy tools like vehicle efficiency norms and fuel standards need to be documented to encourage the adoption of more sustainable transport technologies. Vehicle and fuel pricing are efficient tools, particularly when combined with functional charging infrastructure for EVs. To realize true and lasting climate benefits, electricity would need to be "green". The same is true for hydrogen.

Exhibit-7.3: The Avoid-Shift-Improve Principle in action



Source: Tumi

OPTIONS FOR DECARBONISATION

Transport is a complex system with infrastructure, services, pricing, and social norms influencing a multitude of decisions and behaviour. These system elements need to work together to deliver sustainable mobility. While much can be done at local level where most services are provided, framework conditions are often determined at the national level for legal powers, funding etc., or at international level for technical support, funding or emission reduction obligations, emission trading systems etc. Hence there is a need for coherent and consistent policy action across all levels. The basic elements of a sustainable transport system, including integrated and affordable public transport, safe walking and cycling facilities, car sharing, fuel economy standards, and parking management, should be pursued in parallel to investments in electric mobility. Growing low carbon energy supply and new means of electric transport have generated interest in the potential of electric mobility to transform mobility systems and improve transport for all. However, electric mobility is not without its risks.

The ongoing digitalization of the transport sector offers various opportunities that have the power to accelerate deployment of sustainable mobility. Intelligent transport systems (ITS) allow for more efficient routing and speed control in favour of energy efficiency, intelligent charging solutions and battery management, including vehicle-to-grid (V2G), vehicle-to-everything (V2X) and off grid charging. It also covers sharing means of transportation and rides, integrated multi-modal trip planning and payment systems like MaaS, as well as access & parking management solutions allowing effective implementation of policies that prioritize low carbon, light, and active modes.

A sustainable electric mobility policy must pay attention to the mobility needs of different potential user groups, especially women, disadvantaged and vulnerable groups. The potential user groups need to be identified carefully to ensure access to new means of transport for these user groups. Therefore, challenges such as safety and accessibility must be factored all along the planning and implementation process.

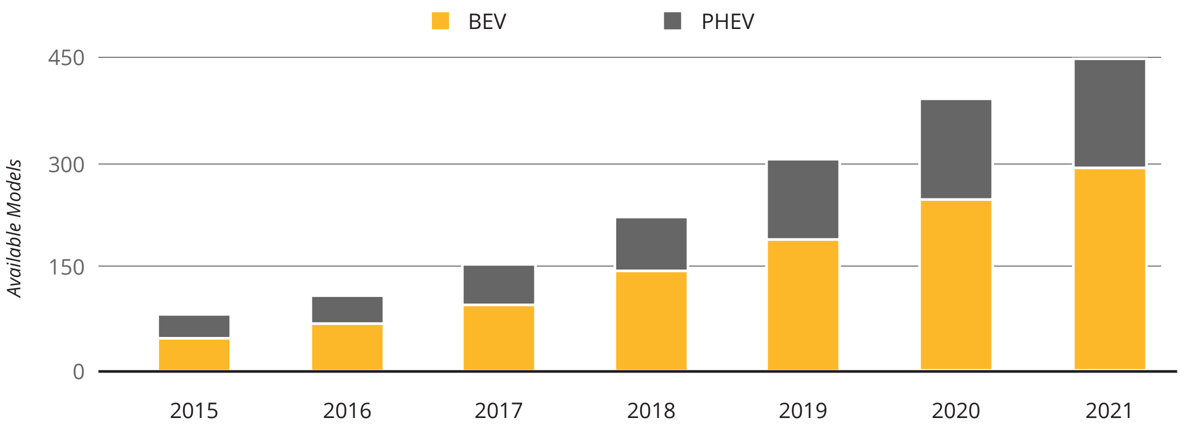
In many countries, affordability is key. For example, in rural areas, electric buses would be too expensive, both from the producer and consumer perspective, but two or three wheel electric vehicles could be transformational. Electric mobility offers excellent potential to drive urban transformation, attract new actors, and trigger private investment in mobility solutions. New electric mobility solutions also provide an opportunity to shift travel to more sustainable and multi-modal mobility patterns, including walking, biking, public transport, and car sharing.

FUTURE OF EV VEHICLES

Road transport electrification continues to expand globally. Sales of electric cars reached another record high in 2021 despite the Covid-19 pandemic and supply chain challenges, including semiconductor chip shortages. About 120 000 electric cars were sold worldwide in 2012. In 2021, that many were sold in a week. After increasing in 2020 despite a depressed car market, sales of electric cars, including battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs), nearly doubled year-on-year to 6.6 million in 2021. This brought the total number of electric cars on roads to over 16.5 million. As in previous years, BEVs accounted for most of the increase at about 70%.

EV markets are expanding quickly. Electric car sales accounted for 9% of the global car market in 2021, four times their market share in 2019. All the net growth in global car sales in 2021 came from electric cars. The number of electric cars on the road reached 10 million in 2020, a 1% stock share. The electric truck stock exceeded 30 000 units, and electric bus registrations are rising. At the same time, a shift towards SUVs and larger vehicles has stalled fuel consumption and CO2 emissions reductions of new light duty vehicles sold globally.

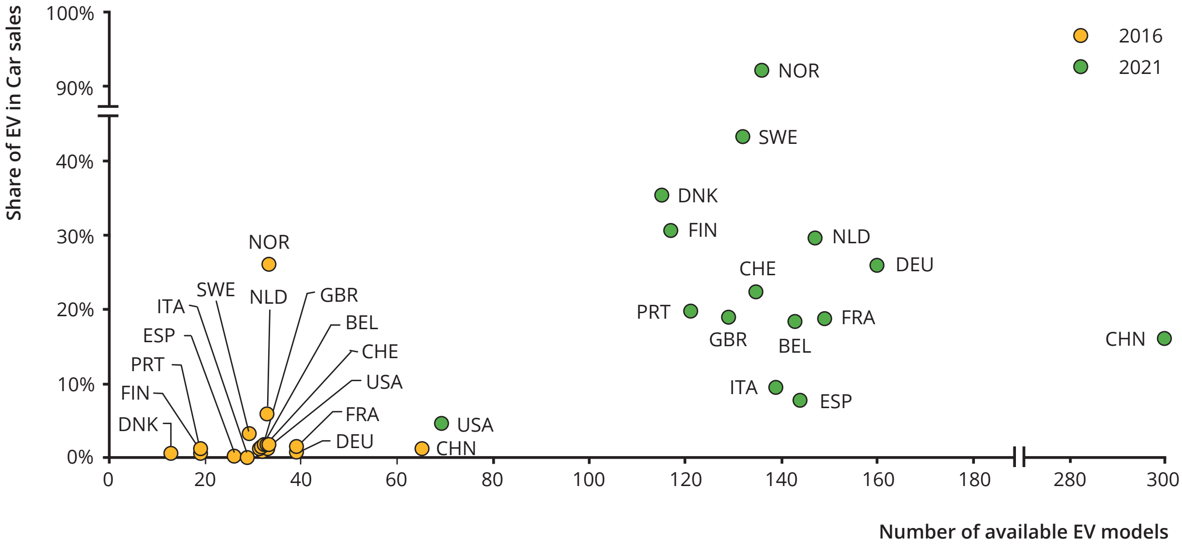
Exhibit-7.4: Status and evolution of electric vehicle model availability, 2015-2021



Globally, over 450 electric car models were available in 2021, an increase of more than 15% relative to 2020 offerings and more than twice the number of models available in 2018. Between 2015 and 2021, the CAGR for new models was 34%. The increase in available EV car models is accompanied by a notable increase in sale volumes in all markets. This reflects the interest of automakers to capture the EV market share by producing new options quickly to appeal to an ever broadening pool of consumers.

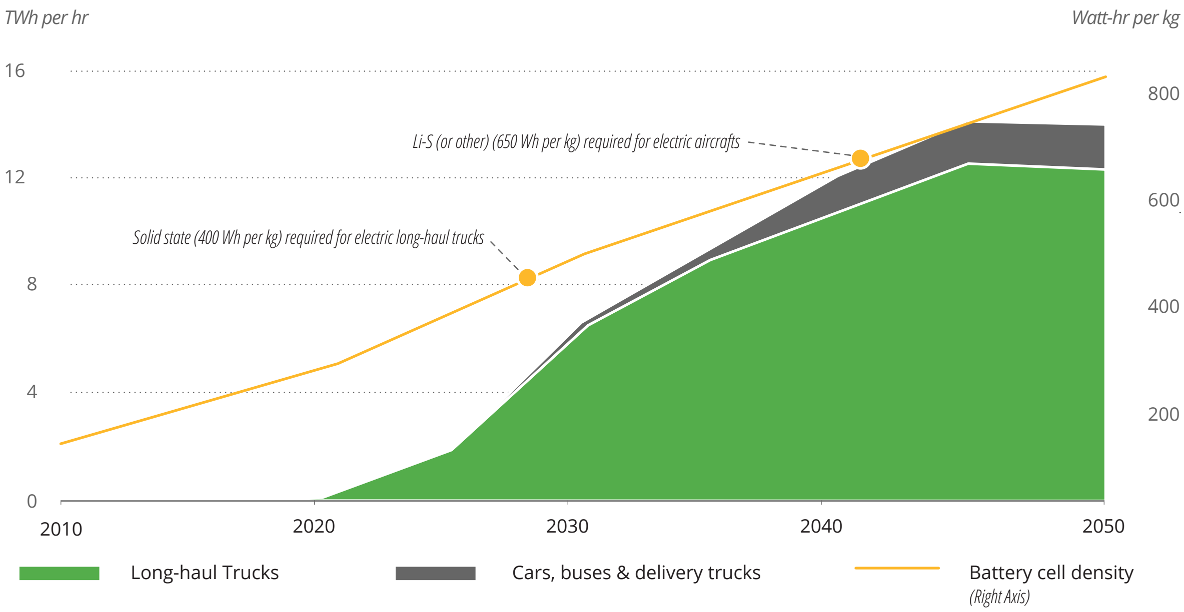
The share of electric vehicles will increase from less than 2% in 2020 to around 45% in 2050. More than 60% of total passenger car sales globally are expected to be EVs by 2030, compared with 5% in 2020. The car fleet will be almost fully electrified worldwide by 2050, and remainder is estimated to be hydrogen powered cars. The increase in electric passenger car sales globally over the next ten years is estimated to be more than twenty times higher than the increase in ICE car sales over the last decade. Electrification is going to be slower for trucks because it necessitates higher density batteries than those currently available in the market, especially for long-haul trucks. On new high-power charging infrastructure, electric trucks nevertheless will account for around 25% of total heavy truck sales globally by 2030 and around two-thirds in 2050. The electrification of shipping and aviation will be much more limited and will get underway only after significant improvements in battery energy density.

Exhibit-7.5: Number of available EV models relative to EV sales share in selected countries, 2016 and 2021



Nearly 20 battery giga-factories are projected to open annually until 2030 to satisfy battery demand for electric cars in the net zero emissions scenario (NZE). Higher density batteries are needed to electrify long haul trucks. In the NZE, demand for batteries for transport will reach around 14 TWh in 2050, 90 times more than in 2020. Growth in battery demand translates into increasing demand for critical minerals. For example, lithium demand for batteries will grow 30 fold by 2030 and will be more than 100 times higher in 2050 than in 2020[6]. Some revolutionary changes in battery technology and substantial improvements in sodium and zinc-based battery solutions will further contribute towards faster developments in various end uses, with mobility being the primary beneficiary. As a summary, to meet NZE's energy efficiency milestones and

Exhibit-7.6: Power demand for a EV-centric transport sector



[6] IEA,2021

emissions trajectory, stringent fuel economy standards, as well as supportive government policies and corporate commitments, will need to ensure changing the ratio of electric & ICE vehicles sold. Additionally, fuel economy of heavy road vehicles must improve continuously, with electric and fuel cell vehicles making up 30% of heavy trucks sold in 2030. HEV, FCEV, PHEV and FFEV can also play a dominant role in India given push from Government of India for bio-fuels.

Many fuels and technologies that offer potential for long-term decarbonization of transport modes for which emissions abatement is challenging tend to be in the very early stages of development. The range of zero emission heavy duty vehicle models in road transport continues to expand. Still, experiments in high pressure, high throughput hydrogen refuelling and charging options for heavy freight trucks tend to be treated as proof of concept activities only.

POLICIES TO PROMOTE EV DEPLOYMENT

Governments are boosting policy to promote EV deployment, build charging infrastructure and secure supply chains

Today most EV charging takes place at residences and workplaces. Consumers will increasingly expect the same services, simplicity and autonomy for EVs as for conventional vehicles. Publicly accessible chargers worldwide approached 1.8 million charging points in 2021, of which a third were fast chargers. Nearly 500,000 chargers were installed in 2021, more than the total number of public chargers available in 2017. Publicly accessible fast chargers facilitate longer journeys. With more deployment, they will enable longer trips, encourage consumers who lack access to private charging to purchase an EV, and tackle range anxiety as a barrier to EV adoption.

Fast charging is being rolled out at a quicker pace than slow charging in China, where fast charging installations (power rating >22 kW) increased by over 50% to 470,000 fast chargers in 2021. The drivers behind the rapid deployment of public chargers in China are government subsidies and active infrastructure development by public utilities. Regulatory controls on electricity prices, public charging demand coming from urban dwellers, and increasing electrification of taxis, ride sharing and logistics fleets have improved the profitability of EV charging businesses. The massive speed and scale of the Electric Vehicle Supply Equipment (EVSE) rollout led to reductions in the costs of manufacturing charger modules for fast charging stations by 67% between 2016 and 2019. In contrast to 2020, when Europe's fast-charging installations significantly outpaced slow charging ones, installations were about the same in 2021. The number of public fast chargers in Europe went up by over 30% to nearly 50 000 units. The 2014 Alternative Fuel Infrastructure Directive (AFID) regulates public electric vehicle supply equipment deployment in the European Union (EU). The policy recommended that EU member states reach ten light duty electric vehicles (LDVs) per public charger by 2020. The proposed new EU legislation, the Alternative Fuels Infrastructure Regulation (AFIR), would mandate 1 kW of publicly available charger per BEV and 0.66 kW per PHEV, as well as the minimum public charger coverage on highways. The Fit-for-55 package in the European Union brought forward a host of policy and stimulus measures to accelerate ZEV transitions. These include a proposal for 100% ZEVs by 2035 through its CO_2 emissions standard and new mandated charging infrastructure deployment targets set under the AFIR proposal for both light duty vehicles (LDVs) and heavy duty vehicles (HDVs).

In the United States, a key EV market, the federal government announced its first targets, including 50% EV sales by 2030 and 500,000 public chargers. The targets are underpinned by existing incentives and new funding packages of US$ 7.5 billion to build charging infrastructure and US$ 3 billion for advanced battery supply chains under the Infrastructure Investment and Jobs Act. New EV market entrant countries are creating conditions to support electric mobility. Common measures include tax benefits and cuts in customs duties for EVs and their components.

Government expenditure on subsidies for electric cars doubled in 2021

Strong policy measures to boost nascent EV industries have been used over the years in some markets, e.g. China and European Union. Now some markets, such as China, Korea and United Kingdom, are steadily reducing per vehicle direct subsidies in recognition of the ongoing closing of the gap between the purchase price of electric and conventional cars, and to push auto manufacturers to lower costs.

Governments announced more ambitious ZEV targets and policies in 2021 than ever before

Following the pathfinders for ZEV deployment, the number of countries that have announced some form of ZEV or electrification target increased significantly. Some employ a CO_2 target which, in effect, would ban ICE cars by requiring zero tailpipe emissions. It has become increasingly clear that a growing number of countries have incorporated the electrification of cars and trucks as a key part of their strategy to reduce emissions as outlined in Nationally Determined Contributions or net zero targets. Strategic direction / incentives provided by national & state governments can provide pivotal signals to shift investment to secure EV supply chains and for OEMs to develop a wide variety of affordable ZEV car and truck models as manufacturing companies seek to meet stricter regulatory requirements & net zero commitments.

Leading countries announce ZEV targets to decarbonize medium- & heavy-duty vehicles

Momentum to catalyze ZEV deployment in heavy duty vehicle segments picked up considerably in 2021. With decreasing costs and improvements in battery performance, the potential to electrify certain operations and vehicle types above 3.5 tonnes of gross vehicle weight is paired with a realization of the transformative impact of electrifying these operations to achieve global climate goals. In 2021, 15 countries representing roughly 5% of global medium and heavy duty vehicle [M/HDV] sales announced support for the 'Global Drive to Zero' campaign. These countries demonstrated their support by committing to the first global Memorandum of Understanding (MoU) on Zero Emissions Medium and Heavy Duty Vehicles. Signatories intend to work together to achieve 2030 and 2040 targets for new ZEV truck and bus sales. Progress towards these goals will be reported annually, and signatories are to develop plans to support such ambitions. Thirty nine companies, subnational governments and other key stakeholders also endorsed the MoU, signaling additional industry support for these ZEV targets.

Adoption of digital technologies & smart charging can alleviate the need for grid upgrades

Uncoordinated EV charging risks are compounding concerns for grid operators to balance supply and demand and placing additional pressure on networks. This could necessitate additional investment in peaking resources. The impacts can be difficult to manage, especially at very high EV stock penetrations and in systems with a weak grid. Coordinated smart charging of EVs offers the potential to help smooth increases in peak demand. Time of use tariffs can facilitate demand side response by giving consumers price signals to shift EV charging to off-peak periods. A practical approach to minimize the need for grid investment due to EV loads will be to make network constraints known at a granular level, identifying areas under the most stress, including at the distribution system level. This allows smart charging to be tailored accordingly. A major precondition for smart charging business development is the ability to control the charging of a large number of EVs. Interoperability allows aggregators to pool vehicles more easily and without cumbersome procedures and interventions at consumer residences. This is key to smart charging development. Standards should be robust and cover cybersecurity, data accessibility and minimum requirements applicable to both private and public chargers.

IMPLICATION OF ELECTRIC VEHICLES

Electric vehicles reduce the use of oil in transport that lowers government fuel tax revenues

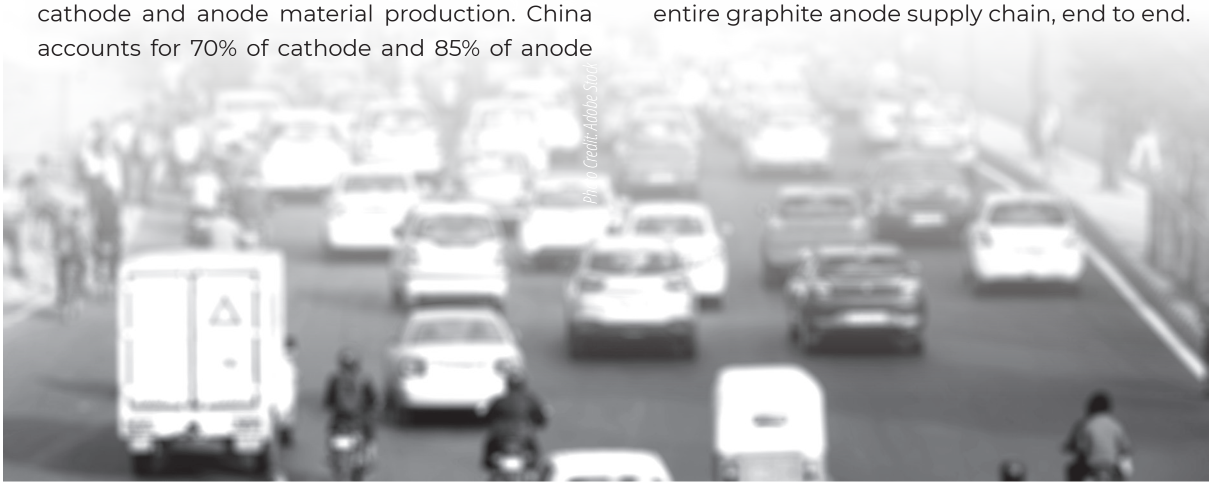
Reductions in government taxes due to EVs are limited today. However, the scale of the global EV fleet by 2030 implies a possible net fuel tax loss of almost USD 75 billion in the Stated Policies Scenario and USD 90 billion in the Announced Pledges Scenario. Europe is expected to see the largest net loss of around USD 35 billion in 2030 due to the relatively high tax rate on oil products. It will be important for governments to anticipate this reduction in fuel tax revenues and design mechanisms that enable continued support for EV deployment while limiting the impact on tax revenue. A principal way to deal with the issue in the short term is to flexibly adapt existing taxation schemes to changes in the fuel market, balancing the net decline in use. However, these short-term measures cannot be protracted in time, as they risk creating distortions and equity issues. The longer term measures to stabilize tax revenues involve deeper reforms in tax schemes. These, for example, could include coupling higher taxes on carbon intensive fuels with distance based charges. Road taxes or distance based charges applied to EVs serve better as longer term measures once price parity has been reached, so EV adoption is not slowed in the short term.

Battery metal prices increased dramatically in early 2022, posing significant challenge to EV industry

High battery demand has spurred significant increases in demand for key metals used in their production. Between the beginning of 2021 and May 2022, lithium prices increased more than seven times, and cobalt prices more than doubled. Nickel prices almost doubled over the same period reaching levels not seen for nearly a decade. If metal prices were to remain at levels experienced in the first three months of 2022 throughout the rest of the year, it is estimated that battery pack prices might increase by up to 15% from the 2021 weighted average price, all else being equal. To meet the demand for projected EV deployment, various elements in the supply chain will need to expand. In the long term, recycling will contribute significantly to supply. However, only minor contributions from recycling are expected by 2030, particularly for lithium and nickel.

China dominates entire downstream EV battery supply chain, but investments underway worldwide

China dominates production at every stage of the EV battery supply chain mining downstream. Three quarters of battery cell production capacity is in China, and the same is the case for specialized cathode and anode material production. China accounts for 70% of cathode and 85% of anode material global production capacity. Over half of global raw material processing for lithium, cobalt and graphite also occurs in China. With 80% of global graphite mining, China dominates the entire graphite anode supply chain, end to end.



THE STORY IN INDIA

Transport Sector accounted for 4.9% of India's gross value addition and 14% of the country's greenhouse gas emissions in 2019. In passenger mobility, considering India's low rate of car ownership (22 cars per 1,000 people), a high share of non motorized transport and shared mobility and a rapidly growing domestic innovation ecosystem, the country has an opportunity to leapfrog over a car centric paradigm to a shared, electric, and connected passenger mobility future. In freight transport, considering India's skewed modal share where 71% of India's freight transport is road based and only 17% is rail based, less fuel efficient vehicles and low operational efficiency, India has an opportunity to shift to a cost effective, clean, and optimized freight transport system.

India is charting its path towards offering cleaner fuels in the transport sector.A major shift to cleaner fuel is also required in the transport sector. Two-wheelers and three-wheelers are already shifting towards electric, and it is anticipated that by 2030 these will have completely shifted away from fossil fuels, so manufacturing of fossil fuel-based two-wheelers and three-wheelers will get phased out over a period of time. Four-wheelers, including passenger cars and taxis, are expected to shift partially to electric, and the rest to ethanol blended Petrol. Roughly 50% of these would be in each of these two categories in the long run. Ethanol-blended Petrol with up to 40% Ethanol could be targeted in the long run and can be considered close to clean fuel if emissions across the value chain on Well to Wheel basis are taken into account. In the medium term, say up to 10 -15 years, CNG-driven four-wheelers may also continue.

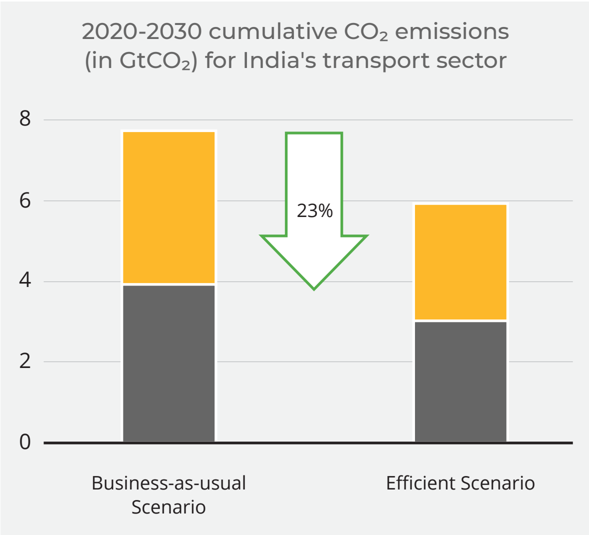
City buses are likely to be totally electric, and city transport has to be a mix of electric buses and Metro. By 2030, no city buses should be added which are not electric. CNG may continue till 2035, but diesel buses for city transport should not be added from 2024 onwards. Long-distance buses will have to be a mixture of electric with battery swapping and CNG/LNG. For this, mechanism for the smooth movement of electric buses across states must be ensured. A major shift of passenger and goods traffic to Railways would also be required to achieve a lower carbon footprint in surface mobility, as railways are likely to be fully electrified in coming years. India needs to work on an integrated multi-modal logistic model to reduce the carbon footprint and cost of logistics in the entire value chain.

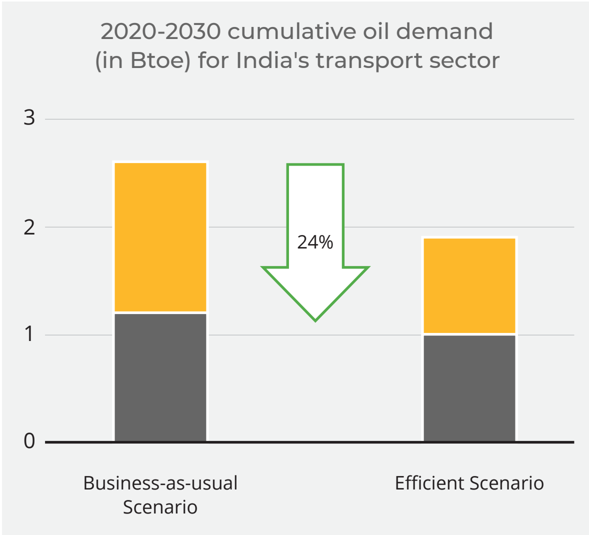
Cargo Railway's share is currently at ~23% nationally. This should go up to 50% in the next 15 years. Trucks should shift to LNG until other fuels like Hydrogen or Green Methanol become a feasible option. Small and medium vehicles deployed in cities for the delivery of goods can shift to electric because they operate within the city and, therefore, they don't have to travel long distances.

India has shown a strong commitment to electric passenger mobility through the FAME II scheme, the National Mission on Transformative Mobility and Battery Storage, guidelines on EV charging infrastructure from various ministries and the announcement of state EV policies in eight states. A supportive policy environment has also been created in freight segment through 'Make in India,' an initiative to encourage domestic manufacturing along with 'Digital India,' a program to transform India into a digitally empowered society and Logistics Efficiency Enhancement Program, which aims to improve infrastructure, procedures, and information technology. Business leaders are capitalizing on these emerging markets by creating new products and business models. New models in electric two- and three-wheeler segments, indigenous mobility as a service and food delivery service platforms have been instrumental in India's move towards clean mobility. The Auto Expo held in February unveiled new models of electric four wheelers and two wheelers that hit the Indian market in 2020. Experts believe that despite the Covid 19 impact, EV market growth will continue in light mobility segments, such as two wheelers, rickshaws, and autos.

To maintain its momentum in energy transition in transport, India must continue to prioritize shared, electric, and connected passenger mobility and cost-effective, clean, and optimized freight transport. Together, India's passenger and freight transport sectors can avoid about 600 Mtoe of oil equivalent (Rs 20 lakh crore of oil import savings) and 1.7 gigatonnes of tailpipe carbon dioxide emissions by 2030.

Exhibit-7.7: Efficiency to reduce oil demand and CO_2 emissions





Reductions in passenger mobility, fuel demand, and emissions can come from reducing demand for motorized mobility through non-motorized transport, working from home for those populations who can do so, and shifting to more efficient modes of transport such as public transport and shared mobility. Additionally, switching to EVs while improving the efficiency of internal combustion engine vehicles that remain on the road will be important. Reduction in freight transport fuel demand and emissions can come from shifting long-haul freight from road to more energy-efficient and less carbon-intensive rail, making vehicles more efficient and electrifying them where it makes economic sense, and optimizing logistics and operations.

KEY TRENDS TOWARDS DECARBONIZATION

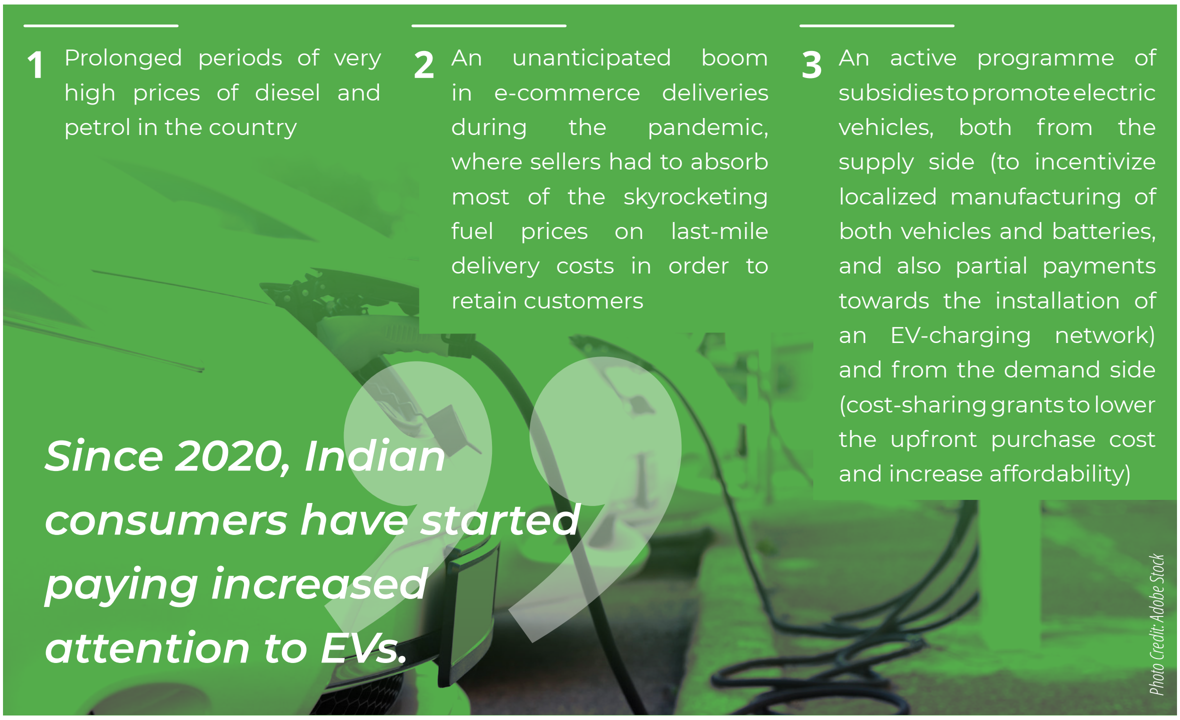
- Road-based transport represents ~40% of global oil demand. Countries dependent on oil imports, such as India, view electric mobility transition as a potential opportunity to gain energy independence. As India continues to grow and urbanize, accelerating EV penetration is becoming increasingly important for the nation.
- In India, the electric vehicle (EV) transition is one of the key elements for realization of a sustainable transportation future. The nation's target of 30% EV penetration by 2030 would be a vital step towards India's major sustainability goals. So far, EV adoption has been slow, however, there is tremendous potential for electrification due to the country's rapidly increasing demand for transportation.
- India extended its EV demand stimulating FAME II Policy till 2024. It also increased subsidies for electric two-wheelers, made budgetary commitments for battery swapping and development of EV manufacturing & battery supply capacity.
- The year 2022 would witness a greater penetration of electrification, self-driving technology, new fuel cell technology, smart charging, great thermal management technology in electric vehicles.
- In last two years, the COVID-19 pandemic has changed the face of the mobility industry, gradually shaping up the industry's operations and products. Trends are expected to continue in 2022.

RECENT FACTORS IMPACTING ELECTRIC MOBILITY

1. Prolonged periods of very high prices of diesel and petrol in the country

2. An unanticipated boom in e-commerce deliveries during the pandemic, where sellers had to absorb most of the skyrocketing fuel prices on last-mile delivery costs in order to retain customers

3. An active programme of subsidies to promote electric vehicles, both from the supply side (to incentivize localized manufacturing of both vehicles and batteries, and also partial payments towards the installation of an EV-charging network) and from the demand side (cost-sharing grants to lower the upfront purchase cost and increase affordability)



Since 2020, Indian consumers have started paying increased attention to EVs.

Photo Credit: Adobe Stock

The biggest factor by far driving shift towards alternative transport solutions is petrol and diesel price, which has been breaking new records for nearly two years. At the start of 2020, before the pandemic, the average nationwide retail petrol price at the pump was INR 69 per litre (just under $1); by mid-2021 it had crossed the psychological threshold of INR 100 per litre and on 19 April 2022, it stood at INR 112 (just under $1.50). Indian retail pump prices for most of 2020 and 2021 bore little relationship to global crude oil prices due to taxes. This was deliberate, resulting from the government's decision to retain and add to legacy tax rates on petrol and diesel and compensate for other sources of government revenue that had dried up with loss of economic activity.

In short, the public perception is that high excise duties & state VAT levies on petrol and diesel may prevail over near term. The ongoing global geopolitical situation raises the spectre of severe disruption of international supply chains, which are critical for sustained product supply, especially in the backdrop of India having increasing dependence on oil & gas imports. Therefore, considering EV and ethanol-based vehicles as alternatives to ICE vehicles and how to make them affordable becomes a matter of increasing awareness and urgency.

DECARBONIZATION POLICIES

In the last few decades, policymakers have largely focused on expanding transport infrastructure to meet skyrocketing demand. The main strategy has been augmenting infrastructure for all transport modes. The road sector has seen the largest outlay, leading to massive growth in road connectivity. An estimated 44% of all transport funds are allocated for road construction alone[7]. The development of urban transport infrastructure has also been a key area of focus. The National Urban Transport Policy, JNNURM, Smart city project, and AMRUT are some recent urban policies with a focus on transport. While these policies have overarching goals of promoting holistic and integrated transport, implemented projects have largely focused on improving road infrastructure. The bulk of expenditure by city governments on transport infrastructure still focuses on building new roads, bridges, and flyovers[8]. In the past, the policy focus has been on enabling mobility to meet the goals of economic growth and social development. With the multi-fold increase in transport activity, recent environmental issues associated with carbon emissions and air pollution have come to the fore. Policy actions have also adapted to these needs and policies related to decarbonization have come up in the recent past. Significant efforts have already been undertaken by the State and Central Governments for implementing decarbonization policies in the country. Some of the most prominent ones are listed in the table. There is a real positivity and acceptance of the need for a clean carbon-free transport sector from all stakeholders.[9]

Transport sector stakeholders, including governments, have been largely missing from COP meetings and other climate change policy processes since the creation of the Convention in 1994. In fact, the transport sector has often been coupled with the energy sector at COP meetings, where transport mitigation actions under discussion were limited to alternative fuel sources. However, the transport sector has been progressing in innovative ways where mitigation measures have gone far and beyond energy-related solutions. Initiatives to decarbonize the sector while allowing for more inclusive mobility include managing transport demand and mode shift using economic instruments, better infrastructure, shared mobility services, traffic management, integrated land use and transport planning and changes in regulatory frameworks, including parking and vehicle restrictions. These measures are effective for climate action and support the advancement of national climate goals towards attaining successful energy transition and net zero compliance.

Table-7.1: India's policy landscape supporting EV propagation

		Policy Instruments		
		Market-based	Regulations	Infrastructure-based
Policy Approach	**Improve**	» Faster Adoption and Manufacturing of Electric Vehicles (FAME) Scheme » State-level EV Policies » Scrappage Policy » Green Tax	» Auto-fuel Policy 2015 » National Policy on Biofuels, 2018 » CAFE-1 » CAFE-2 (upcoming) » Fuel efficiency standards for M /HDVs » Acceptance of hydrogen and LNG as automotive fuel	» National Electric Mobility Mission Plan » National Hydrogen Mission » Electrification of Railway operations » CNG program » Focus on empowering ethanol usage in transportation
	Shift			» National Rail Plan, 2020 » Waterways Act, 2016 » Higher budget allocation for buses and metros » JNNURM Scheme
	Avoid / Reduce			» National Transity Oriented Development (TOD) Policy » Urban Green Mobility Fund » Smart Cities Mission

7 Sharma and Rajput 2017

8 Shakti 2017

9 https://www.teriin.org/sites/default/files/files/Decarbonization_of_Transport%20Sector_in_India.pdf

PROPOSED ALTERNATIVE PATHWAYS FOR SURFACE TRANSPORT

The shift towards decarbonization will require increased use of natural gas, ethanol and biodiesel/renewable diesel as a transport fuel, and thus demand for these fuels is likely to increase.

LNG is especially expected to be an attractive solution for hard-to-abate heavy-duty vehicles. In 2019, the consumption of natural gas in India stood at 60 billion cubic meters, of which only 27 billion cubic meters was produced in the country (India Energy Statistics, 2019). Presently, less than 2% of the demand for natural gas is from the transportation sector. However, in various decarbonization scenarios, demand for natural gas from transport is estimated to grow at a high CAGR of 9.78% between 2020 and 2050, reaching 421 TWh by 2050. Given the limited availability of natural gas reserves within the country, this would require a significant increase in gas imports. In addition to imports, considerable public and private investment will be needed to build storage and transport infrastructure, including LNG terminals and gas pipelines.

Biofuels are currently the most viable replacement for fossil transportation fuels as they can be used with legacy Internal Combustion Engines (ICE). As witnessed in the case of global biofuels demand, even in India, demand for ethanol/biodiesel as a fuel will be primarily driven by blending mandates, widespread availability of fuel and compatible vehicles up to limited blending percentages, and fulfillment of other infrastructural requirements. As discussed in earlier section, the demand of ethanol is to grow to over 1000 Crore Liters by 2025-26, backed by introduction of ethanol powered (flexi-fuel or hybrid vehicles). Similarly, biodiesel consumption is expected to increase with increase in accessibility of raw materials. For a deep dive into Biofuels, see Chapter-4. Further improvements on Hybrid Technology will result in achieving higher mileage per unit of fuel, which will result in significant in carbon footprint.

The current hydrogen demand in India is primarily focused on the chemical and petrochemical sector. Increased penetration of FCVs in intercity buses and HCVs will lead to hydrogen demand rising from zero in 2020 to 149 TWh by 2050, reflecting a significant increase in the share of hydrogen use in transportation. This would require a major augmentation in hydrogen production capacity in India. As hydrogen is produced rather than extracted, the costs associated with production are likely to be higher than natural gas. There is also a debate regarding whether the focus should be on producing blue hydrogen and then shifting to green hydrogen or whether the focus should be on directly enabling a shift to green hydrogen. The latter option is likely costlier but would lead to major environmental benefits and prevent technology lock-ins as the cost of green hydrogen production comes down. The key aspects influencing the production costs of green hydrogen include the cost of electrolyzers and the price of renewable energy. The cost of electrolyzers has declined in Europe and North America by almost 40% since 2014. A recent study by BNEF suggests that renewable hydrogen could be produced for between US$0.7 and US$1.6/kg by 2050 in most parts of the world (Bloomberg New Energy Finance, 2020). Investments would also be required to create the right infrastructure for hydrogen transportation. However, it would require a highly coordinated program of infrastructure upgrades as hydrogen is incompatible with existing pipelines. Some tests to assess level of hydrogen mixing without upgrading the network are already underway.

Governments, automotive manufacturers, energy companies, charging infrastructure operators, mobility service providers, technology providers and aggregators across the globe are preparing themselves for a rapid transition from conventional internal combustion engine (ICE) vehicles to electric mobility. Electric vehicles are expected to account for nearly 57% of all vehicle sales and over 30% of all vehicle fleets by 2040, increasing from global sales of 2.1 million units in 2019. Therefore, Government of India is steadily moving towards a “shared, connected and electric” mobility ecosystem to achieve its stated goals on emissions reductions, energy security and industrial development. It is doing so through wide ranging policy and regulatory measures to encourage adoption of greener options like CNG, ethanol and EV adoption, creation of public charging infrastructure and incentivizing domestic EV / battery manufacturing facilities.[10] To meet the enormity of challenge, India would need to transition surface mobility to CNG / biofuels mixed fuels and then to hybrids & EVs.

POSITIVE DEVELOPMENTS

- Consistently high public investment in roads and bridges has led to the rapid expansion of road network and increased rural connectivity.
- Focus on enabling electric mobility with policy push through purchase and manufacturing initiatives at both Central and State levels.
- Promising adoption of electric vehicles in segments such as two- & three-wheelers.
- A dynamic automobile manufacturing industry actively focused on partnering in a shift to electric mobility.
- Proliferation of metro systems in urban areas providing an alternative to private vehicles.
- Focus on improved vehicle efficiency through ambitious fuel efficiency norms.
- Early recognition and focus on identifying a clear roadmap for enabling alternate fuels like biofuels, natural gas and hydrogen.
- An extensive railway system is poised to play a key role in decarbonization with an aim to become a net-zero system by 2030.
- Adoption of economic instruments such as scrappage policy and green taxes to incentivize a shift to newer efficient vehicles.
- Successful deployment of CNG vehicles in some cities for commercial operations

KEY GAPS AND ISSUES

- Coordinated policy planning & comprehensive roadmap for mobility sector decarbonization is lacking, too many government agencies are involved in transport planning.
- Electrification is most relevant for limited road transport segments, these include two-wheeler, three-wheeler segment, passenger cars, light commercial vehicles, & urban buses.
- Hard-to-abate road segments, long-distance buses, and heavy-duty vehicles account for more than 40% of total energy consumption, deep decarbonization depends on finding solutions for these segments. CNG and ethanol mixed fuels can suit these requirements.
- Low share of rail in freight and passenger movement, more investments required in rail infrastructure to enable modal shift.
- For EVs to gain scale, it is necessary that a uniform policy regime is created and appropriately calibrated in the face of emerging global trends and domestic realities. EV buses can be the preferred mode of road transportation, helping reduce carbon footprint and congestion on roads. These policies need to be cohesive, uni-directional and aligned at the central and state level to ensure fast adoption of EVs across India.
- Transport planning capacity remains limited leading to mobility plans not getting implemented. Lack of differentiated strategies for cities based on existing mobility patterns.
- Technology transition is heavily dependent on clean power. However CNG and Ethanol with lower carbon footprint need to be promoted to initiate the process of emissions control.
- Solutions need to be identified for the aviation and shipping sector as demand for these sectors increases rapidly.

[10] https://openknowledge.worldbank.org/bitstream/handle/10986/35655/Electric-Mobility-in-India-Accelerating-Implementation.pdf?sequence=1&isAllowed=y

RETAIL REFUELLING INFRASTRUCTURE

The availability of retail fueling stations is one of the biggest hurdles to consumer acceptance of low carbon vehicle technologies. A significant scale up in retail fueling infrastructure would be required for alternate fuels to compete. This would necessitate a major increase in the penetration of electric vehicle supply equipment (EVSE), natural gas dispensing stations and hydrogen refilling stations as and when hydrogen enters the scene. The capital costs associated with setting up an EVSE and hydrogen station could be threefold and six-fold higher, respectively, even in 2050. Thus, the cost of retail infrastructure for newer fuels will likely be significantly more expensive in the short and long run. In this regard, ethanol/biodiesel blending with no change at retail outlet level is ideally limited as an immediate measure. This translates into higher expenditure on retail infrastructure for newer fuels compared to a petroleum dependent pathway. Given that EVs have a lower range than their ICE counterparts, the density of EVSE in urban areas will also likely be higher. Retail infrastructure will have to be established not only in urban areas but also on all major intercity routes, and specific guidelines will also have to be developed for this as well.

Table-7.2: Fuel-wise cost estimates for setting up new refuelling stations

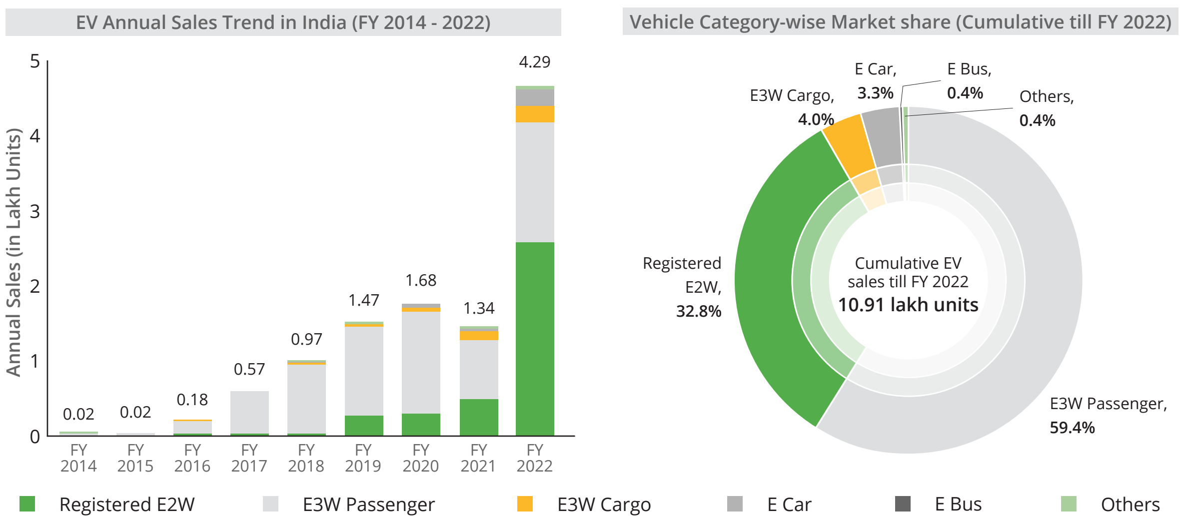
Capital cost per 100 miles	Gasoline Station	CNG Station	Hydrogen Station	EVSE
2020	$2.14	$8.80	$13.31	$9.89
2050	$2.14	$7.78	$8.60	$6.09

Source: Melaina, et. al., 2013

GROWTH FORECAST FOR EV IN INDIA

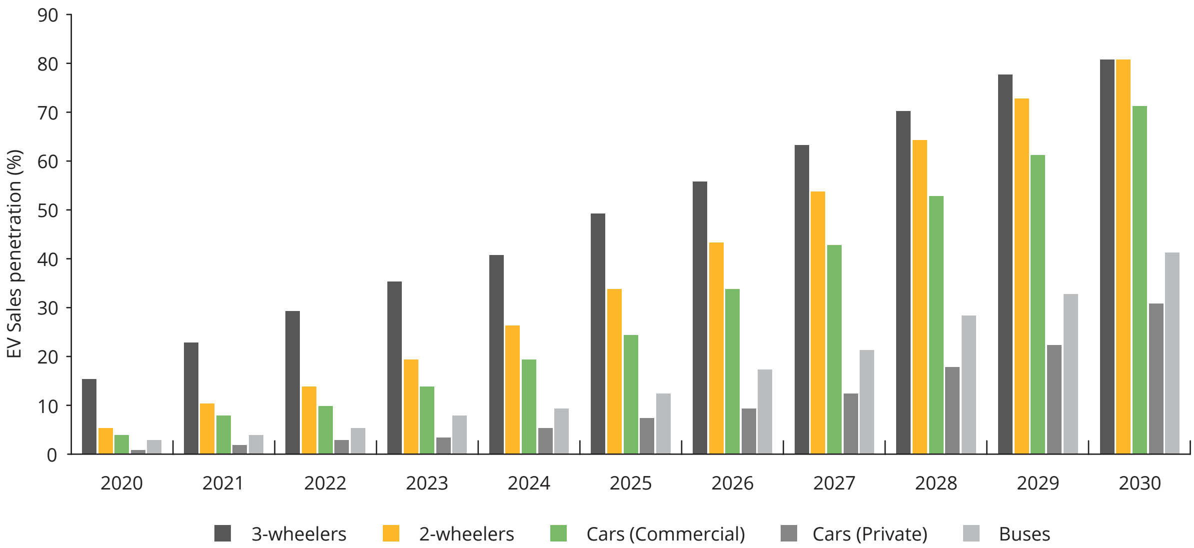
According to Society of Indian Automobile Manufacturers (SIAM), nearly 17.5 million internal combustion engine (ICE) vehicles were sold in fiscal year 2021-22 in India. As per the Federation of Automobile Dealers Association, retail sales of electric vehicles clocked 4,29,217 units in FY22 (April 2021-March 2022), as compared to 1,34,821 units in FY21 (April 2020-March 2021) and 1,68,300 units in FY20 (April 2019-March 2020). Owing to the largely unorganized sector of 3w or e-rickshaws, it is reported that around 1,79,706 units could have been sold in FY 22. Of the total number of vehicles sold so far by FY 22, the majority (32.8%) were two wheelers. Based on total ICE sales and EV sales, it is clear that the annual EV sales, as percentage of total vehicle sales, is still below 2.3% in India.

Exhibit-7.8: EV Growth in India



It is estimated that India could achieve 30% EV sales penetration around 2030 because of existing policies. It could reach 55% if aggressive measures are implemented to achieve the goal of limiting the global temperature rise to below 1.7-1.8°C by 2030 in India. EV sales penetration will be 80% for two and three wheelers, 70% for commercial cars, 40% for buses and 30% for private cars. Approximately 80 million EVs are expected to be sold in 2030. Of that 70% are expected to be two and three wheelers, and the rest will be cars and buses. In the FAME-II scheme, out of the total fund of US$ 1.3 billion, nearly 35% is allocated for e-Buses and 25% for electric three wheelers for public transportation. Therefore, the transition of public transportation to e-mobility is one of the top priorities for the central government.

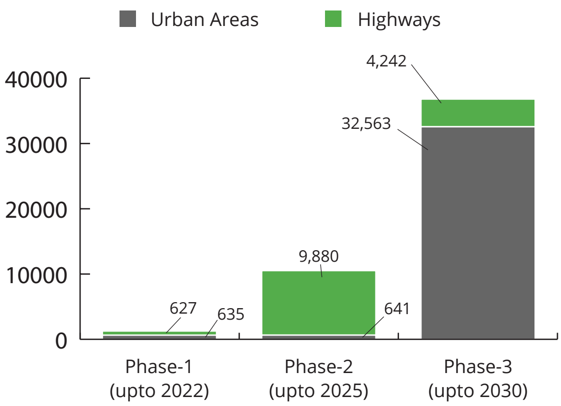
Exhibit-7.9: EV Penetration in India



GROWTH FORECAST FOR EV CHARGING INFRASTRUCTURE IN INDIA

By the end of FY 2021-22, there were 4305 publicly accessible EV chargers in India, of which only 15% were fast chargers. It is observed that the number of fast chargers is minimal as compared to the number of slow chargers. To increase the availability of public chargers, the Ministry of Heavy Industries sanctioned 2,636 charging stations across 62 cities in India under the FAME-II scheme in January 2020. Out of the 2,636 charging stations, 1,633 will be fast charging stations, and the remaining 1,003 will be slow charging stations. The Government of India aims to promote EV adoption by providing public charging infrastructure every 3 kms within cities and at every 25 km on national highways and to facilitate destination charging across multi-storied buildings and commercial centers. Considering only the minimum requirements laid down by the Ministry of Power regarding density/ distance between two public charging stations (PCS), the estimated number of PCS for the rollout of EV public charging infrastructure in India is depicted in the figure.

Exhibit-7.10: Estimated number of public charging stations in India



Presently, many electric cars or electric two wheeler owners charge their EVs at home. According to research reports, 60-70% of Indian vehicle owners do not have a dedicated parking space at home. With a lack of dedicated parking spaces for vehicles, public charging will be more prevalent in the future in India, as compared to home charging. It is estimated that if India has around 50,000 charging stations by 2030, with nearly 2,50,000 publicly accessible charging points, then this will result in an investment opportunity of around US$ 6 billion for public & private sector organizations. This will result in increased demand for both electricity and associated grid infrastructure.

SITUATION ON THE GROUND

Less interest in shared transport, more interest in private vehicles and modes

- While ridership of public transport is expected to decline in the short term, this price-sensitive market may not be able to switch modes easily, making it important to strengthen and improve public transport options, especially bus systems and metros.
- Ridership of shared and ride-hailing services like Ola and Uber has dropped by as much as 60 percent during the work-from home shift.[12]
- Car-sharing platforms, such as Zoom, expect a three-fold increase in demand as consumers have higher safety perception.[13]
- Indian consumers may seek to move away from shared mobility options and invest in two- and four-wheelers, as well as second-hand products, which are available at affordable price points.[11]
- Last-mile modes will be affected due to lower passenger mobility demand and use of public transport, with shared modes like electric rickshaws and autos being the most affected.

Robust demand for EV products for low speed two and three wheelers and pick up in demand for electric four wheelers and e-buses to be accelerated in the medium term.

- Rising disposable incomes due to economic growth and a tendency towards fuel cost saving will lead to accelerated demand for EV products.
- Under the gross cost contract model, e-bus operators may not have the capital to run buses, and OEMs may not want to own and operate their own buses. However, a new business model on revenue sharing basis without incurring upfront Capex is being adopted by STUs, which may pave the way to overcoming the capex issue.
- Many OEMs have added or are planning to add new models for their EV business portfolio in various vehicle segments, such as Tiago EV by Tata Motors, XUV400 electric SUV by Mahindra and Mahindra, EQS 580 India's first locally manufactured luxury EV by Mercedes-Benz, Montra Electric 3W Auto by TI Clean Mobility, 3W- OTUA for logistics, last-mile delivery by Dandera Ventures etc.
- There is huge potential for various customer segments to rapidly pick up in short to medium term, including corporate customers and last mile logistics firms.

[11] *https://www.pwc.in/assets/pdfs/services/crisis-management/covid-19/impact-on-the-automotive-industry-and-navigating-the-turbulence.pdf*

[12] *"Uber restarts partial operations in India; recovery will vary across geographies, says CEO," Economic Time Tech, 9 May 2020*

[13] *https://www.deccanherald.com/business/shared-mobility-to-remain-subdued-firms-gear-up-for-post-covid-phase-834378.html*

Absence of robust localized supply chains

While local supply chains are not fully established, curbs on imports of Chinese components may lead to disruptions in EV manufacturing.

Impacts of Financing

Due to rising safety concerns and rising interest rates, there may also be declining venture capital funding in the EV and mobility startup space. The situation may, however, improve as the safety concerns recede with concerted efforts by manufacturers and regulators.

Impacts on Policy Change

Many state EV policies and e-bus projects may be delayed due to other priorities, given fuel prices inflation, shortage of raw materials and rising prices of critical minerals and commodity.

Picture Credit: Adobe Stock

KEY RECOMMENDATIONS[14, 15]

GENERAL

Continuation of FAME II scheme beyond 2024

▪ FAME II	FAME II scheme has already been extended till 31st March 2024. The government might need to evaluate the targeted extension of the scheme based on progress and specific needs (dedicated charging for E-buses, mushrooming pick up in uptake of 4w, e-buses and high speed two wheelers etc.) to continue to enable the alternate fuel ecosystem in India.
▪ Expansion of charging infrastructure	The accelerated pace of approvals may be continued for charging infrastructure to expand reach beyond the 68 cities, which are already approved and cover all the high volume national highways.
▪ Subsidy for deployment of EV chargers	Under the scheme, subsidy to OMCs for the deployment of one or more EV Chargers (Type CCS II - DC) in OMC retail outlets in any of the following capacities or a combination thereof depending upon feasibility: 25 KW – 30 KW capacity, 50 KW – 60 KW capacity, 100 KW and above. OMCs may be given the freedom to fix prices based on fair return on investment in view of lower footfalls for charging in the near term.
▪ Public charging infrastructure	Public transportation offered by State Transport Undertakings faces twin challenges, such as limited charging infrastructure and upfront financing. Fame II may also encompass suitable and graded provisioning for expanding charging infrastructure for city buses. Public charging infrastructure, including heavy duty vehicles and buses in tier 2 and tier 3 cities, must be improved to promote wider public e-mobility.
▪ Non-motorized transport infrastructure	Create an urban road retrofit program to support more accessible walking, cycling, and electric micro-mobility solutions to offer clean, safe mobility alternatives and create jobs.
▪ Quantum of FAME subsidy per EV	Increase the quantum of FAME subsidy per EV, rather than targeting more EVs with lesser subsidy, with a focus on most sustainable vehicle segments, to offer gap viability and linking the cost parity with ICE counterparts for accelerated adoption of EVs other than low speed two and three wheelers.

[14] https://openknowledge.worldbank.org/bitstream/handle/10986/35655/Electric-Mobility-in-India-Accelerating-Implementation.pdf?sequence=1&isAllowed=y

[15] https://www.niti.gov.in/sites/default/files/2022-01/Banking-on-EV_web_2.0a.pdf

Public transport upgrade and expansion

▪ Public transport upgrade and expansion	Create an initiative to enhance reliability in public transport, including the procurement of more buses, the adoption of e-buses, designs for new buses and corridors and bus rapid transit systems, and the digitization of public transport. This may also include alternative funding sources and revenue models, such as advertising and real estate assets. Substantial action on this front has already been taken or is understood to be in the offing. While working towards this, the following aspects may also be considered: » City buses of different sizes should be put on the road instead of standard-size buses to serve diverse mobility needs. For cities, OEMs should be encouraged to come up with a range of models for launching as per the diverse needs of the public transportation system and prevalent environmental acts and regulations. » Major players in the promotion of public transport are state transport departments and urban bodies. However, they are financially weak. Some schemes like pay per Km and revenue sharing have to be explored and launched. Any gap that may arise in the process should be funded by the respective state governments by providing suitable budget allocations. The broad objective should be to apply economies of scale to offer the masses convenient, efficient and affordable public transport. » Electric trams as means of public transport may also be explored. Batteries or electric lines can be explored as an innovative measure to ensure last mile connectivity.

National level strategy for freight expansion and optimization

An integrated national strategy for optimizing and digitizing freight sector & its supply chain may be developed. The recently unveiled National Logistics Policy may end up being a game changer for developing long-term wholesome solution for passenger & goods transport.

▪ Mode shift of long haul goods to rail	Encourage shifting of long haul bulk goods movement from road to rail based transport with complete electrification of the traction with renewable power. The modal share of railways in India is much lower than most other countries with a developed rail system. An ideal modal mix would require a significant increase in the share of rail in passenger and freight movement. However, the railway's infrastructure and marketing policies also need to keep pace with the road segment due to the paucity of investment and rigid administrative structures. Enabling modal shifts will require improving capacity to enable better transit times, especially for freight services. Already significant investments are being done in terms of dedicated freight corridors, high speed rail, track, and rolling stock augmentation. As per recent plans, railways aim to cater to the needs of 24% of freight transport, which is estimated to increase to 35% by 2030 and reach 50% by 2050. Such an aggressive plan can be dovetailed to facilitate the most efficient rail based long haul transport solutions.

▪ Electric delivery vehicles	Issue guidelines to state governments to encourage the electrification of last mile delivery vehicles and light duty commercial vehicles plying on dedicated routes as freight demand n increases over the next one to two years. State governments could potentially push last mile logistics companies to continue with their EV deployment plans and create awareness about the benefits of electrification amongst delivery operators. Some dedicated schemes may be put in place by state governments for LCV electrification on dedicated routes.
▪ Freight corridors	Encourage the development of several electric freight corridors to promote use of LNG and the electrification of the medium and heavy duty truck segment.
▪ Foster innovation in low-carbon technologies for heavy-duty long-distance segments	There are no clear frontrunners for low or zero emission technologies for HDVs, intercity buses, and aviation. The future availability of technologies will depend upon the pace of innovation in potential technologies. Some steps for nudging innovation are outlined below: » *State and central governments* (i) Direct funding and support for research organizations involved in low carbon technology research, such as fuel cells, battery technology, and storage technology. (ii) Establish courses in premier public institutions related to electric mobility and fuel cell technology. (iii) Technology agnostic economic incentives for low carbon trucks and buses could facilitate the uptake of the most cost effective technologies. This would require providing subsidies and increasing taxes based on carbon emissions, regardless of the technology. (iv) Most e-buses procured by State Transport undertakings (STUs) ply for intra-city movements, with some operating on inter-city routes. To give further momentum for wider EV bus adoption, it is vital that a more robust ecosystem is created so that these vehicles can ply effectively with minimal approvals across various neighboring states. (v) Some measures to promote public transportation are outlined below: – *EV policy by all states / UTs: As of now, only 20 states and UTs have notified or are about to declare the EV policy. All the states and UTs are required to put forth an EV policy whose key attributes should be uniformly aligned among the states for supporting such expansions and attracting investment for more variants of e-buses.* – *Mandate fleet addition and phased conversion: Mandate state and local agencies to add more EV bus fleet. There should be a requirement to convert a certain percentage of fleets to electric power within a specified period of time.* – *Develop government procurement guidelines: Establish standardized guidelines to streamline the e-bus procurement process and facilitate government purchases.* – *Permit exemption by all states / UTs: The permit required for inter-state movement of buses should be exempted by all the states and UTs in unison. Central portals like Vahan could be used to facilitate the smooth inter state operations of EVs. For the adoption of e-buses, permitting inter state movement will help create economies of scale.* – *Effective utilization of EV related infrastructure: The central government should encourage state governments to create hubs and depots for e-Buses capable of providing charging, maintenance, boarding lounges and basic facilities for commuters and drivers essential for safe driving in a pre-agreed business construct for inviting PPP bids where the state government arranges land and electricity connectivity based on a long term lease.*

- Foster innovation...

  (continued from previous page)

  » *Original equipment manufacturers*

(i)	Increased funding for R&D of low carbon technologies.
(ii)	Set targets for shifting away from the manufacture of diesel trucks and buses.
(iii)	Engaging in international collaborations to import knowledge related to electric, hybrid, and fuel cell vehicles.

Improve the efficiency of the logistics sector

The road logistics sector in India is characterized by obsolete vehicles and fragmented markets (RMI India NITI Aayog, 2021). This leads to inefficient operations causing poor fuel economy, wasteful trips, and overloading. Streamlining logistics movement could enable significant emission reductions.

- Central Government
  - » Fuel economy standards and emission standards for trucks should be revised periodically. This should be done in consultation with truck manufacturers to ensure feasibility and timely implementation.
  - » Ensure strict enforcement of standards through periodic monitoring of the on-road performance of trucks.
  - » Introduce attractive economic incentives to promote the scrapping of older trucks.
  - » Improve warehousing location through better data collection related to the origin and destination points. This can be aided by leveraging existing data available from the GST e-way bill system.
  - » Relook at biofuel policy. Identify enabling cost-effective pathways for 2G biofuels.

- Private logistics operators
  - » Ensure optimal usage of truck capacity.
  - » Periodic upgrade of obsolete vehicles.
  - » Improve placement of warehouses to improve load factors and reduce empty trips.
  - » Utilize larger size trucks.

Non-motorized transport infrastructure

Create an urban road retrofit program to support more accessible walking, cycling, and electric micro mobility solutions to offer clean, safe mobility alternatives and create jobs.

THE PROLIFERATION OF HYBRIDS / EV

Constitution of a stakeholder's dialogue forum

Consult the EV industry, OMCs, EV fleet operators, EV corporate consumers and other stakeholders to understand the required changes and formulation of comprehensive mobility policy. The key focus should be to gradually move the sector towards selling only Hybrid, CNG, flex/flex hybrid vehicles and electric vehicles, starting with the four wheeler fleet segment, where a time-bound mandate might be considered, which can be further spread out to other CV / PV segments.

Supporting charging and battery swapping infrastructure expansion

- Charging infrastructure
    - » Charging infrastructure installation to be focused on top EV-demand cities in the early stages of the market. Expansion to other cities must be evaluated when top cities have achieved a certain density and saturation level of public EV charging infrastructure.
    - » Establish a simplified and fast-track approval process for EV chargers. Also, rate the DISCOMs on their process for providing EV charger approvals as part of the ease of doing business matrix.
    - » Some other vital measures that can be considered for the rapid development of charging infrastructure have been enumerated below:

(i)	DISCOMs to bear the cost of the upgradation of electrical infrastructure required for the installation of charging stations under the RDSS scheme.
(ii)	Waiver of fixed demand charges on EV power connection.
(iii)	Mandatory concessional EV tariff by all State DISCOMs
(iv)	Single window time-bound approval for EV power connection
(v)	Allow electrical load up to 250 KW to be on LT.

- Battery Swapping infrastructure
    - » In line with battery swapping getting included under Ministry of Power guidelines, subsidy support for the battery swapping model in the FAME-II scheme may also be developed.
    - » In order to make minimal policy and regulatory changes, the swappable battery could be provided along with the vehicle, and the subsidy could be provided to the OEM just like it is currently being done for vehicles with factory-fitted batteries. The OEM could pass on the subsidy to the battery swap operator, which would reduce the price of the swapping service and ultimately pass the benefit on to the end consumer.
    - » Reduce GST on swappable batteries, charging service and battery swapping service from 18% to 5% in line with GST rates for EVs, EV chargers and factory-fitted batteries in EVs

Focused revision / updation in EV policies

▪ State and central government	» A rating and incentive system for manufacturers based on share of EVs in their production basket could lead to more EVs entering the market. » Large scale public investment to establish charging and swapping stations in public places. This would aid in creating a critical mass of infrastructure, incentivizing increased private investment. Standardization of battery and swapping form factors may be critical to achieve this move. » Awareness campaigns to highlight the benefits of EVs and provide practical information may go a long way in resolving the concerns and myths about EVs and educating the masses. » Promote indigenous manufacturing of batteries by identifying long term sources for raw materials and providing economic incentives linked to localized advanced chemistry with high energy density. Additional government efforts to localize the manufacture of batteries and cells and the use of public resources to fund R&D on alternative battery technologies under PLIs and the national program for Advance Chemistry cell moving away from lithium-ion chemistry will help lower battery costs, develop high energy density battery (over 400 Wh/Kg) and speed up the adoption of e-mobility across all income levels of society. The advance chemistry cell batteries should be stipulated to be high energy density to make them compatible and feasible for wider adoption in heavy duty vehicles. » Develop regulations to encourage the organized EV retrofitting market and increase organizational capacity to ramp up the certification infrastructure for safety considerations. » Institute fleet transition trajectories for certain “obligated entities,” such as large fleet operators for certain vehicle segments over fixed timelines. » Provide higher incentives for replacing old vehicles with EVs compared to ICE vehicles under the current Vehicle Scrappage Policy. » Support micro credit access for electric two and three wheelers for microfinance institutions through the MUDRA scheme. » Supplement lower cost, longer tenure DFI financing to support micro credit access for e-2W and e-3W; and work closely with OEMs to explore additional risk reduction models such as extended warranties, buyback offers & residual value guarantees to increase confidence among financiers about EVs.
▪ Original equipment manufacturers (OEMs)	» Collaborate with OMCs to tailor relevant EV models based on specific use cases in view of affordability related issues through established retail network. » Identify risk sharing mechanisms to distribute the risk of financing EVs due to uncertain resale value. » Coordinate and share data with financing institutions to allow better evaluation of EV performance.

Explore ways to commoditize and standardize battery option

The real challenge for India lies in electrifying two and three wheelers used by nearly a billion people in the country daily. Converting these vehicles to electric, making them affordable and convenient, and doing what it takes to turn e-two and three wheelers into the first preference over ICE vehicles when making a purchase decision should be supported and measured. The adoption of e-mobility through the individual purchase of EVs is not likely to happen very fast in the mass segment of the market of180 million families or 900 million people, even for two wheelers with leased batteries selling at a price point today of under Rs. 78,000. Even the battery leasing option, amounting to an estimated Rs. 7,000 per month for a gig worker, is a financial stretch. This is extremely important in a low income consumer market where high cost products such as lithium-ion EV batteries are supposed to be adopted by consumers who are struggling financially. Despite the billions that the government has set aside to lower the upfront cost of entry, it appears that the product may still be out of reach for most of the budget market, until the battery costs and battery leasing costs fall further. India's ongoing attempts to standardize a subset of swappable batteries for the light vehicle segment, to make them interoperable across multiple vehicle brands, are likely to increase affordability and create market confidence as one type of battery becomes 'commoditized'.

OVERCOME OVERARCHING POLICY CHALLENGES

Apart from the specific actions mentioned above, the transition to a low carbon transport sector will require certain institutional adaptations. The shift away from the present gasoline dependent system will also create ripple effects in other parts of the economy. Some of the issues that need addressing are highlighted here.

Establish institutions for holistic transport planning

The transportation sector is at the beginning of a period of significant disruptions. For instance, governance in urban transport is multifaceted, where various players influence the overall quality and quantity of transportation infrastructure and its service provision. Governance plays a pivotal role in implementing transport policies. A healthy operating institutional framework is necessary for successful policy implementation. The policy implementation draws multiple agencies under one hood to achieve the desired targets. Presence of multiple actors in policy implementation makes establishing and managing these arrangements difficult. The responsibility of implementing different strategies for decarbonizing transport sector in India lies with different central and state agencies. To coordinate actions for transport sector, there is a need to have a specific institutional framework involving central & state government institutions for transport planning.

Sustained inflow of investment in transport infrastructure

Petroleum taxes contributed over 2% of GDP in the last decade. During FY 2010–17, on average 45% of India's union taxes (from customs and excise duties) and 26% of state taxes (from sales tax) were collected from the petroleum sector. Reduced consumption of these fuels will have a direct effect on government revenues. To ensure that the loss in revenue does not affect investment in decarbonization infrastructure, alternate sources of revenue will need to be established. Congestion pricing, limiting subsidies, and user access charges for using public infrastructure could be some of the strategies for mitigating this issue.

Ensure coordinated investment in low-carbon infrastructure

Going forward, stricter criteria will need to be evolved while assessing investment in transport infrastructure. There should be a focus on the lowest cost options while giving higher importance to investment in low carbon infrastructure. This will necessitate some judgments regarding the ideal modal mix as well as the segment wise potential of alternate fuel options. Better coordination among different government agencies at the central and state level will also be essential.

Differentiated planning for cities

National-level policies and fund allocation must account for city level differences in mobility patterns. Investment priorities should be in line with the particular city's characteristics. This would require further empowering of the city level transport agencies financially and with technical capacities.

At the same time, it is noted that the national transportation sector gained specific attention through the Jawaharlal Nehru Urban Renewal Mission (JNNURM) and the National Urban Transport Policy (NUTP) policies, which required a revision to accommodate updated policy relevance. These policies aim to improve and establish a safe, accessible, comfortable, and affordable public transportation system, reduce vehicle growth, encourage hybrid/electric vehicles, and manage air pollution. These policies require the urban local bodies of major cities to prepare Comprehensive Mobility Plans (CMP) to address local transportation issues. At present, there is a lack of comprehensive policy preparation and evaluation criteria which creates a gap in achieving the desired target. This is one of the reasons why the CMPs do not significantly impact on reducing transportation problems, and as a result, private vehicles continue to grow. A relevant CMP must be developed, aligning with national and state objectives and dovetailing local requirements.

OVERALL TECHNOLOGY AND PATHWAY CHOICES FOR INDIA

As discussed earlier, surface transportation accounts for nearly three fourth of all emissions caused in the entire mobility value chain. It is therefore, critical that urgent multi-pronged actions are taken to address these emissions and eliminate those overtimeover time.Current predominantly fossil fuels based surface mobility needs to progressively move towards a lower and eventually to zero carbon footprint options. In this regard, Chapters in this report have been included on Gas & Biofuels, where specific issues relating to these and recommendations to increase their role in surface mobility have been discussed.

It is clear that Indian surface mobility towards net zero will need deployment of all lower / zero emission options till the end objective of zero is achieved. So Natural Gas/Bio CNG for cars and city distribution smaller trucks, LNG for heavier trucks and mobility in identified corridors, and increasing mixture of ethanol in petrol and biodiesel with diesel, will, all need to be incentivized. It is also felt that the Hybrids can play a critical role in improving the mileage per unit of fuel, thus helping bring down the resultant carbon footprint. So during the transition journey, India may establish an ecosystem for all options to flourish and avoid technology lock-ins. Similarly, an overall system of incentives and policy push for these emerging options is needed such that the effective relative carbon footprint is the broad criteria for the building incentive regime to individual options. However, for Bio CNG / Ethanol and Biodiesel, which are expected to play a critical role in reducing emissions, it is necessary that the anomalies arising on account of the dual GST and VAT regime are addressed either by including fuels in the GST regime or working out a system that avoids stranding of the tax credit.

Picture Credit: Adobe Stock

Chapter 8

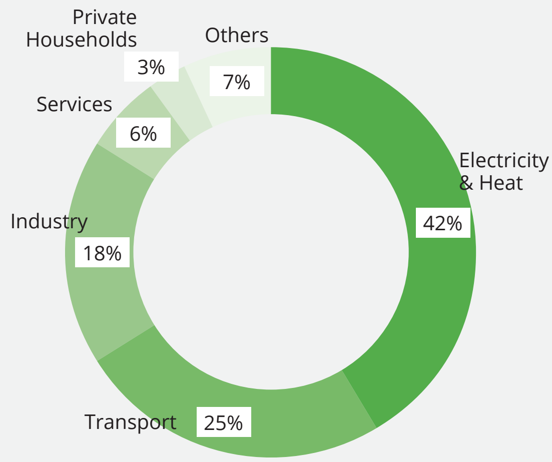
ZERO-CARBON SHIPPING

In this section

SHIPPING INDUSTRY: AT A GLANCE

The shipping industry accounts for around 80 percent of global transportation volume. However, the sector is responsible for only 10 percent of transport emissions and 2-3 percent of total greenhouse gas (GHG) emissions. Compared to other forms of freight transport, shipping is the most efficient in terms of the amount of emissions produced, just 20 to 25 grams of CO_2 per ton-km, compared to up to 600 gm for aviation and between 50-150 gm for road-based transportation, as shown in Exhibit-8.1 and Table-8.1.

Exhibit-8.1: Global emissions, 2018 ($GtCO_2eq$/year – tank to wake)



Source: International Energy Agency (IEA) (2020, 2019); Fourth IMO GHG Study (2020); Intergovernmental Panel on Climate Change (IPCC) (2018)

Table-8.1: Transport sector–specific emissions, 2018

Transport Sector	Ranges for freight ($GtCO_2eq$/ton-km)	Share of global emissions (%)
Road	70–180	~18%
Aviation	400–900	~3%
Maritime	5–45	~3%
Other*	30–60	~1%
Total emissions	**~25%**	

** Rail / unknown transportation means*

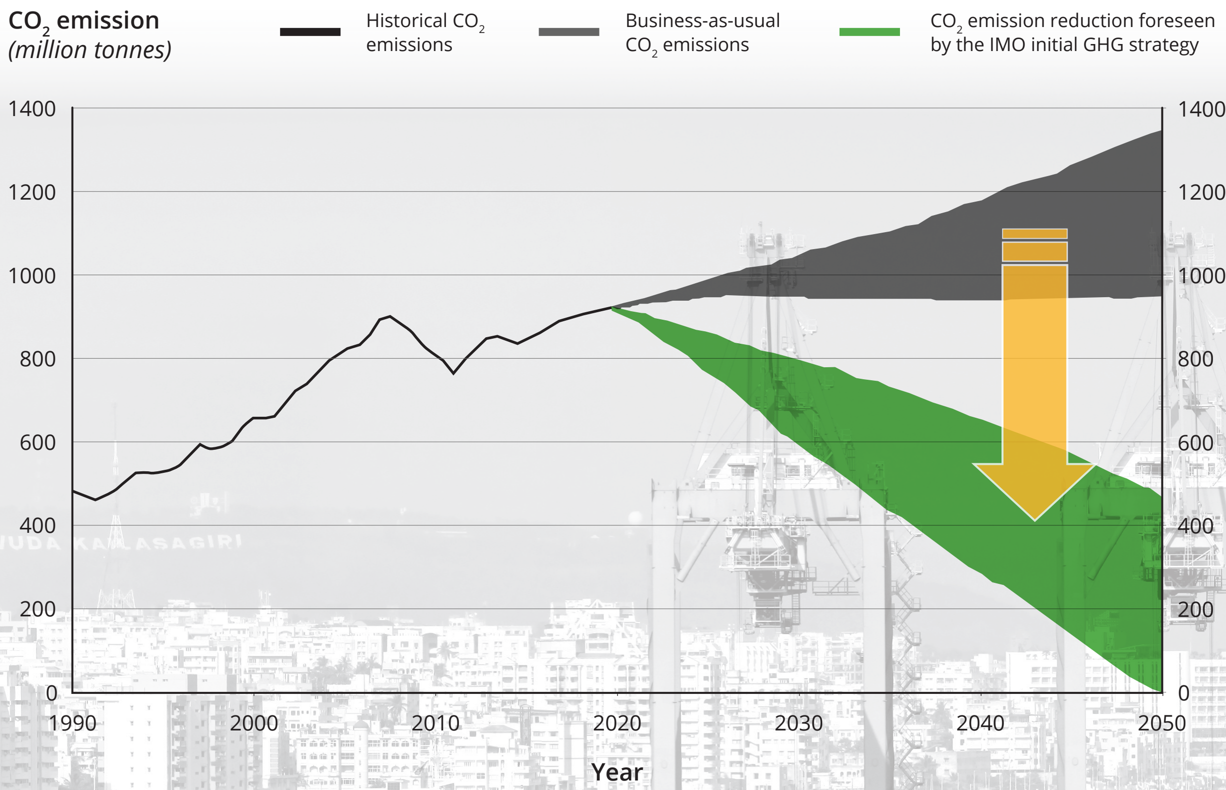
Source: IEA (2020, 2019); Fourth IMO GHG Study (2020); IPCC (2018)

- Shipping volumes are expected to increase by around 1.3 percent on average every year between now and the middle of the century. The industry's CO_2 emissions are expected to increase steadily by 5 - 8 percent of global CO_2 emissions by 2050, compared to 3 percent in 2018, with emissions growing significantly in most dynamic trading regions, e.g. East Asia.
- The maritime industry faces a matrix of challenges on its journey towards zero carbon, which will delay or even prevent the transition if not addressed upfront. Firstly, the maritime industry is a highly complex, global and decentralized sector with more than 1,00,000 commercial vessels. Secondly, the current cost gap between conventional fossil fuels and alternative fuels is very large, leaving hardly any financial incentive to make the switch. Even if ship owners wanted to make the change, supply chain of alternative fuels is not yet ready for global distribution to accelerate transition.
- Three segments—bulk carriers, tankers, and container ships—are responsible for around 65 percent of the shipping industry's CO_2 output. These three categories make up around 90 percent of shipping volume; thus, they contribute the most in terms of absolute emissions volume.
- Short-haul vessels may electrify or adopt hydrogen fuel, while decarbonizing deep-sea vessels will require green ammonia, methanol, or any other fuel with high energy density.

CURRENT GHG STRATEGY:
INTERNATIONAL MARITIME ORGANIZATION (IMO)

In April 2018, the IMO, through its Marine Environment Protection Committee (MEPC), unveiled the Initial IMO Strategy on the reduction of GHG emissions from ships. All 100-plus member nations of the IMO agreed to an ambitious target of reducing annual shipping emissions by at least 50 percent by 2050, relative to 2008 levels. Exhibit-8.2 depicts the projected trajectory. The MEPC highlighted measures such as stricter energy efficiency standards and increased investment in clean energy technologies and alternative fuels, through cooperation amongst public and private stakeholders. Considering the sustained growth in international seaborne trade and the current lack of low-carbon fuel alternatives, the 50 percent reduction target does, indeed, seem ambitious. More ambitious measures could be included in the next revision of the strategy, which is due in 2023.

Exhibit-8.2: The shipping industry's GHG emissions trajectory, as foreseen by the Initial IMO Strategy



Source: World Bank (https://blogs.worldbank.org/)

Photo Credit: Adobe Stock

INDIAN SHIPPING INDUSTRY

India's ports and shipping industry play a vital role in sustaining the growth of the country's trade and commerce. India is 16th largest maritime country in the world, with a coastline of about 7,517 km.

According to the Ministry of Ports, Shipping and Waterways, around 95 percent of India's trading by volume and 70 percent by value is done through maritime transport.

India has 12 major ports and 205 non-major ports (details provided in Exhibit 8.3). The addition of capacity at ports is expected to grow at a CAGR of 5 to 6 percent till 2022, thereby adding 275 to 325 megatons of capacity. Under the National Perspective Plan for Sagarmala, six new mega ports are proposed to be developed in the country.

Ports in India have very ambitious expansion plans. It is anticipated that by 2030, the world's largest port will be in India. In October 2021, the Adani Group announced its intention to make APSEZ a net zero carbon emitter by 2025 and power all its data centers with renewable energy by 2030.

India has one of the largest shorelines in the world, which can be advantageously leveraged to serve as effective means of freight movement. India also has large river systems, which have the potential to be developed as an effective mode of transportation through inland waters in a cost effective and environmentally sustainable manner.

India is a large country, and as such, the movement of goods across the length and breadth of the country would, at times, require more than one means of transportation, depending on the local geographical placement and connectivity. A technologically enabled integrated multimodal end-to-end solution for inland and coastal freight needs to be developed with support from all relevant agencies and stakeholders. This can, over time, be upgraded to integrate the movement of goods relating to imports and exports. For ease of business, it will be critical that a single set of approval / clearances is developed with inputs from all relevant agencies such that over time the movement of goods does not have to require multiple and disjointed approvals. These aspects may need to be appropriately addressed as a part of a holistic national policy.

Currently, various ministries and stakeholders manage matters relating to the movement of passengers and goods. Roads are under the Ministry of Road, Transport and Highways, railways fall under the control of the Ministry of Railway, while goods movement through air and water is handled by the Ministry of Civil Aviation and Shipping. For the seamless movement of goods and to avoid logistic nightmares, it is critical that there is overall coordination among some of these agencies to ensure that India is able to provide world-class logistic solutions at a reasonable cost, minimizing the time taken and in an environmentally sustainable manner. This will also ensure the full utilization of the infrastructure being created by different ministries, e.g., it will help railways capture a higher share of on-land goods movement once its expanded network of 100 'Gatishakti' cargo terminals are commissioned.

Exhibit-8.3: Ports in India

Ports in India

Major

- There are 12 major ports in the country - 6 on eastern coast and 6 on western coast
- >54% of the total cargo is being handled at 12 major ports in India
- Major ports are under he jurisdiction of the Government of India and are governed by Major Port Trusts Act 1963, except Ennore Port, which is administered under the Companies' Act 1956

Non-major (minor)

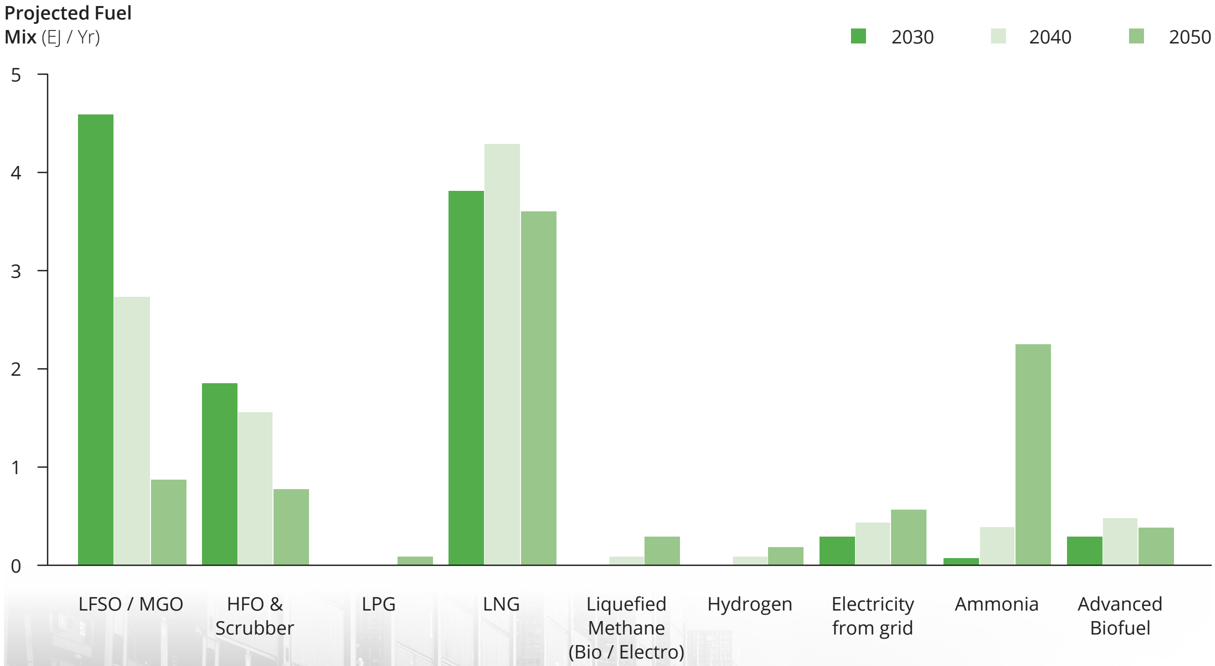
- India has ~205 non-major ports
- Non-major ports account for 46% of the total cargo traffic at Indian ports in FY 21
- Non-major ports come under the jurisdiction of the Governments' Maritime Boards (GMB) of respective states

Source: IBEF, https://www.ibef.org/

MITIGATION STRATEGIES

Efforts are being made to mitigate the adverse environmental impact of oil and gas supply chains through various measures, such as reduced flaring, process optimization, and the utilization of clean fuels, which have been extensively reviewed in fuel utilizing industries. As a result of growing energy security, environmental and economic concerns, policymakers have begun to shift their attention away from fossil fuels. The IMO has imposed stricter restrictions on the emission of sulfur oxides, particulate matter, nitrogen oxides, and other emissions from ships, which is forcing operators to consider other alternatives, such as low sulfur fuel oil (LSFO), marine gas oil (MGO), high sulfur fuel oil (HSFO) in combination with scrubbers, liquefied natural gas (LNG), methanol, ammonia, and hydrogen. Exhibit 8.4 illustrates the projected share of marine fuels by 2030 and 2050.

Exhibit-8.4: Maritime energy demand and projected fuel mix up to 2050



Source: DNV GL Maritime Forecast to 2050, Energy Transition Outlook 2019

Photo by Pixabay: https://www.pexels.com/photo/business-cargo-cargo-container-city-262353/

ALTERNATIVE FUELS

Maritime engineers, naval architects, and other shipping experts are busy evaluating alternative fuels and ways to achieve low or zero emission shipping. These analyses consider the raw materials, production methods, performance, and overall lifecycle emissions of fuels, in addition to other factors, such as the economics of shipping. Methanol and ammonia are expected to play a pivotal role in the decarbonization of the shipping industry by 2050.

METHANOL

- In one study, Joanne Ellis and Martin Svanberg of SSPA Sweden, ship research and testing center, together with colleagues at the Luleå University of Technology, evaluated renewable methanol as a shipping fuel.
- However, there are economic barriers, including capital investment and the fact that bio methanol currently costs more than conventional fuels.
- However, methanol has also been produced from many types of solid and liquid biomass feedstocks, including agricultural and forest residues and farming and poultry waste. Switching to methanol sourced from these biomass sources could lower emissions from shipping and reduce the industry's overall environmental impact.
- Methanol is currently produced mainly via the catalytic conversion of synthesis gas, a mixture of carbon monoxide and hydrogen obtained from reforming natural gas or from coal gasification.
- Methanol offers advantages over some alternative fuels. It is a liquid that is stored, transported, and used at ambient temperature. Its utilization as a shipping fuel would be more straightforward than switching to cryogenic LNG or gaseous fuels such as hydrogen.

AMMONIA

- Over time, India should explore development of an international scale ammonia supply hub catering to regional and domestic shipping industry needs. Considering the traffic movement in the region and the requirement for domestic shipping, it is estimated that India can emerge as a major activity centre in hydrogen and ammonia supply value chain.
- Ammonia can be produced from renewable electricity, using electrolysis to extract hydrogen from water and combine it with nitrogen extracted from the air.
- 90+ percent of world's ammonia production is generated using the Haber–Bosch process. Natural gas is converted to hydrogen through steam reforming and then processed to yield ammonia. In this process, an iron-based catalyst is utilized to combine the hydrogen and nitrogen atoms by subjecting them to high pressure and temperature.
- The ammonia production process contributes about 1 percent to the world's GHG emissions.

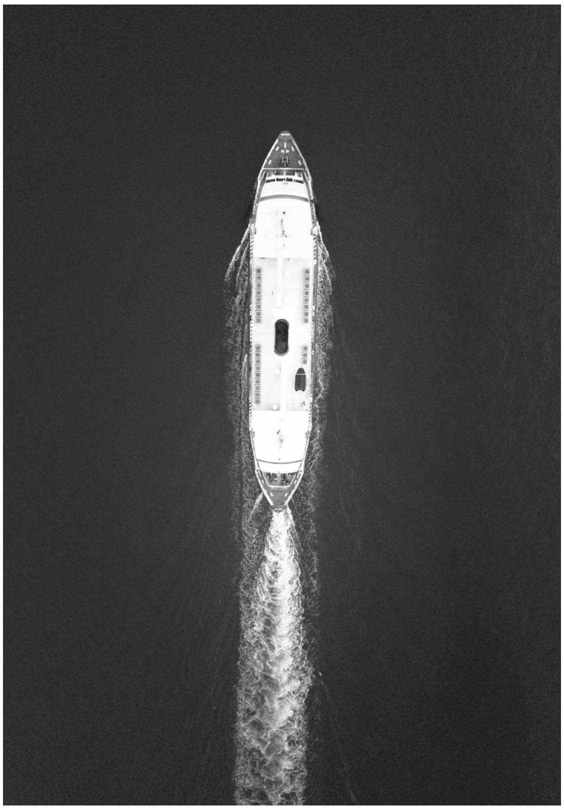


Photo Credit: Adobe Stock

RECOMMENDATIONS

India needs to develop an integrated multimodal end-to-end solution for inland and coastal freight to eliminate the problems currently faced by users of mobility services when the goods are required to be moved through more than one mode. This solution can be upgraded over time to integrate the movement of goods in relation to imports and exports. For ease of business, it will be critical that a single set of approval / clearances is developed with inputs from all relevant agencies such that over time the movement of goods does not have to require multiple and disjointed approvals.

India has one of the largest shorelines in the world, which can be advantageously leveraged to serve as effective means of freight movement. India also has large river systems, which have the potential to be developed as an effective mode of goods transportation through inland waters in cost effective and environmentally sustainable manner.

Currently, various ministries and stakeholders manage matters relating to the movement of passengers and goods. For the seamless movement of goods and to avoid logistic nightmares, it is critical that there is overall coordination amongst these agencies to ensure that India is able to provide world-class logistic solutions at a reasonable cost while minimizing the time taken and in an environmentally sustainable manner. This will also ensure the full utilization of the infrastructure being created by different ministries, e.g., it will help railways capture a higher share of goods movement once its expanded network of 100 'Gatishakti' cargo terminals are commissioned.

Although hydrogen has several obstacles that hinder its development as a bunker fuel, a pathway to its utilization still exists. With further advancements through research and improved technology, hydrogen usage can become an important way forward by mixing the currently used bunker fuels with hydrogen to create a fuel blend that generates fewer emissions at an acceptable efficiency level.

Methanol, ammonia, and hydrogen are good options for replacing the currently used bunker fuels since they are mostly free of sulfur; therefore, their consumption as fuels will have a positive impact on the amount of sulfur oxide and particulate matter emissions. Over time, India should explore the possibility of becoming an ammonia supply hub catering to the domestic and international shipping industry.

GLOBAL INITIATIVES IN ALTERNATE FUELS FOR SHIPPING INDUSTRY

Many leading shipping companies are starting to utilize alternate fuels. Initiatives undertaken regarding clean fuel utilization include the following:

- Germany's MAN Energy Solutions and South Korean shipbuilder Samsung Heavy Industries have undertaken an initiative to develop the first ammonia-fueled oil tanker by 2024.
- A.P. Moller – Maersk is planning to introduce the first in a groundbreaking series of eight large ocean going container vessels capable of operating on carbon neutral methanol. The vessels will be built by Hyundai Heavy Industries (HHI) and have a nominal capacity of approximately 16,000 containers or twenty foot equivalent units (TEU).
- An increasing number of shipping organizations have started viewing hydrogen as their preferred option. The China Maritime Safety Administration authorized the China Classification Society to compile the first national set of technical rules for hydrogen fuel in shipping.
- CMB TECH's Hydroville is a dual fuel passenger shuttle that uses hydrogen to power a retrofitted diesel engine to carry people between Antwerp & Kruibeke in Belgium.

Chapter

9

SUSTAINABLE AVIATION FUEL (SAF)

In this section

PERSPECTIVE ON THE AVIATION INDUSTRY

Photo Credit: Adobe Stock

Aviation is one of six hard-to-abate sectors, the others being cement, steel, plastics, trucking, and shipping. Together, they represent approximately 30 percent of global carbon emissions. According to the European Commission, by the middle of the 21st century, demand for flying could increase aviation's greenhouse gas (GHG) emissions by more than 300 percent from 2005 levels—although this increase has been temporarily slowed by the COVID-19 pandemic.

As travel picks up in the wake of the weakening pandemic effect, aviation will return to producing its share of about 3 percent of total global GHG emissions. Globally, the aviation industry produced 915 million metric tonnes[1] of carbon dioxide (CO_2) in 2019.

With a growing number of countries committing to net-zero emissions targets for their economies by the middle of this century, industries and policymakers are looking at reducing carbon emissions, specifically from the international aviation sector. Prior to COVID-induced reductions, annual jet fuel consumption was about 360 billion liters. This was forecast to more than double by 2050 (Galford, 2019; ICAO, 2019a; OPEC, 2020).

Achieving deep emissions reductions will require new technologies, including modifications to existing aircraft, new propulsion systems such as those in electric and hybrid aircraft (suitable for small aircraft, short-haul routes, and limited passenger numbers), and the use of hydrogen (suitable for short and medium-haul routes and medium-sized aircraft). Although these alternatives are likely to be used in the future, in the short to medium term, the use of sustainable aviation fuel (SAF; fuels that have significantly reduced emissions compared to conventional jet fuel) will predominate.[2]

[1] International Renewable Energy Agency, 2021

[2] International Energy Agency, 2021

COP26 & THE ADOPTION OF CORSIA

Climate change is one of the biggest challenges of our time. It requires collective action to solve the cetral issue of rising emissions, embodied in a shared vision and collaboration across government, industry, and society. The International Aviation Climate Ambition Coalition at the 26th UN Climate Change Conference of the Parties (COP26) has acknowledged the International Civil Aviation Organization (ICAO) as the appropriate forum to address emissions from international aviation through both in-sector and out-of-sector measures to implement short, medium, and long-term goals, including the development of a global sustainability framework to support the deployment of SAF.

ICAO has adopted a market-based measure, the Carbon Offsetting Reduction Scheme for International Aviation (CORSIA), under which aircraft operators would be required to purchase "emissions units" to offset any increase in CO_2 emissions above a 2019 baseline.

CORSIA only applies to international flights, which are defined as flights that take off in one country and land in another. Domestic flights, meaning flights between two airports located in the same country, are not included in the scope of CORSIA. To address the concerns of developing nations and taking into account their special circumstances and respective capabilities, CORSIA will be implemented in phases.

Exhibit-9.1: Phased implementation of CORSIA

PILOT 2021-23	PHASE-1 2024-26	PHASE-2 2027-35
It applies only to the countries that have volunteered to participate in CORSIA	It applies to the countries that voluntarily participated in the pilot, as well as any other countries that volunteer to participate in this phase	All international flights will be subjected to offsetting requirements, except flights to and from the following: ▪ Least-developed countries ▪ Small island developing states ▪ Landlocked developing countries ▪ Countries which represented <0.5% of international revenue ton-kilometers in 2018, unless they volunteer to participate.[5]

- By September 2021, ~107 countries planned to participate in CORSIA from January 1, 2022[3]
- The countries that have volunteered cover ~77% of all international aviation activity[4]

India will not participate in CORSIA's voluntary Phase 1 but will have to participate in the mandatory Phase 2, starting from 2027.

[3] https://www.icao.int/environmental-protection/CORSIA/Documents/CORSIA_States_for_Chapter3_State_Pairs_Sept2020.pdf

[4] https://www.iata.org/en/iata-repository/pressroom/fact-sheets/fact-sheet---corsia/

[5] https://www.icao.int/sustainability/Documents/RTK%20ranking/International%20RTK%20rankings_2018_SIDS_LDC_LLDC.pdf

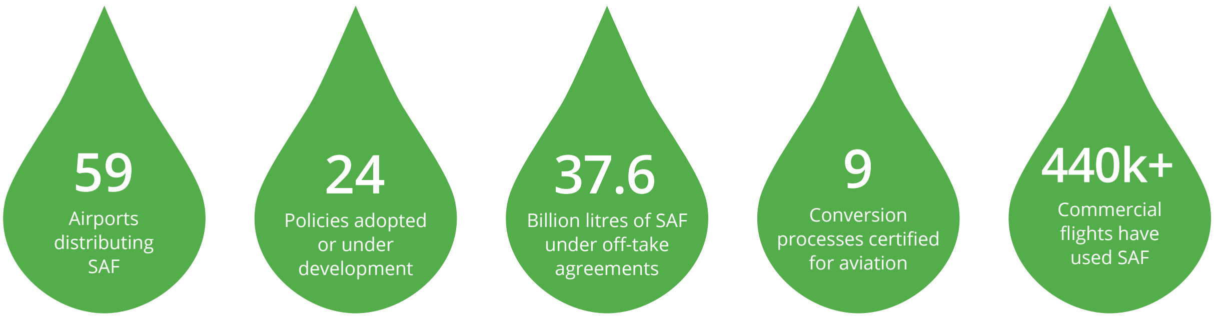
SUSTAINABLE AVIATION FUEL (SAF) GLOBAL SCENARIO

Photo Credit: Adobe Stock

The SAF blending program in European countries, including France, Finland, Norway, Sweden, and the Netherlands, is underway, and these countries are already blending 0.5 to 1 percent SAF in aviation turbine fuel (ATF). SAF are renewable or waste-derived aviation fuels that meet CORSIA sustainability criteria. They are one element of the ICAO basket of measures to reduce aviation emissions. The global shift to sustainable aviation fuel is not just limited to Europe and North America.

Other countries, including Indonesia, Japan, and Australia, have begun to implement efforts to scale SAF. Indonesia was the first country in the world to announce a SAF mandate in 2015, with a 2 percent SAF blend—but it could not implement it due to international unwillingness to permit the use of unsustainable palm based biofuels in aircraft. In 2020, Norway adopted a mandate for 0.5 percent SAF blends.

Exhibit-9.2: Global progress in SAF (as of November 2022)



Source: ICAO Global Framework for Aviation Alternative Fuels

SAF SUSTAINABILITY CRITERIA

For SAF to be an effective emissions reduction measure, SAF producers must adhere to strict sustainability criteria for feedstock and energy inputs, incorporating strong and transparent certifications throughout feedstock supply chain. Under CORSIA, any SAF or CORSIA-eligible fuel (CEF) needs to meet the sustainability criteria set by ICAO.

Exhibit-9.3: Sustainability Criteria of ICAO before & after January 2024

SAF or CORSIA-Eligible Fuel (CEF)

Pre-2024 BASIC CRITERIA	2024	Post-2024 ADDITIONAL CRITERIA
▪ CORSIA-eligible Fuel (CEF) should generate 10 percent lower carbon emissions on a life-cycle basis. The baseline GHG emissions for crude-based ATF are fixed at 89 grams of CO_2 equivalent per megajoule. According to CORSIA, for any SAF feedstock-process product to be accepted as a qualified CEF, it has to achieve a 10 percent or greater reduction in emissions, that is, less than 80.1 grams of CO_2 equivalent per megajoule. ▪ CEF should not be made from biomass obtained from land with high carbon stock.		▪ Maintain / enhance water quality & availability ▪ Maintain / enhance soil health ▪ Minimize negative effects on air quality ▪ Maintain biodiversity, conservation value & ecosystem services ▪ Promote responsible management of waste and use of chemicals ▪ Respect human rights and labour laws ▪ Respect land use rights and land law, including indigenous or customary rights. ▪ Respect formal / customary water rights ▪ Contribute to social & economic development in regions of poverty ▪ Promote food security in deficient regions

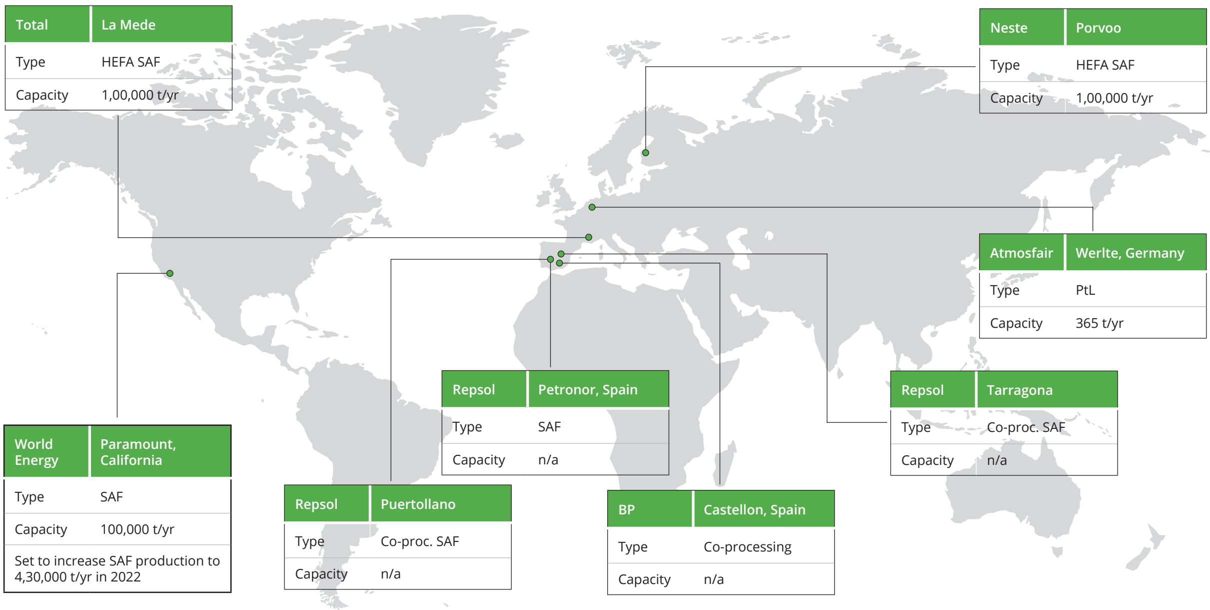
The ICAO Council has allowed fuel manufacturers to collaborate with Sustainability Certification Schemes to undertake fuel certification using the CORSIA sustainability criteria. SAF manufacturers are required to demonstrate that a Sustainability Certification Scheme has certified that their fuel meets the ICAO criteria for CEF and must do so before airplane operators can use the SAF to claim emissions reductions under CORSIA.

ICAO approved Certification Schemes

Roundtable on Sustainable Biomaterials (RSB), Switzerland	International Sustainability & Carbon Certification System, Germany

SUSTAINABLE AVIATION FUEL (SAF) CURRENT PRODUCTION & POLICIES

Exhibit-9.4: Global SAF production facilities (operational)



Source: Argus, April 2022

Exhibit-9.5: Global SAF Policy Highlights

5

SAF Policies have been adopted globally

Country	Policy Status	Policy Type	Description
Brazil	Adopted	Economic incentive	**National bio-kerosene program:** The policy directs federal agencies and institutions to provide resources to SAF projects, as well as fiscal incentives.
Norway	Adopted	Mandate	**0.5% SAF blend mandate:** Started in 2020; considering a 30% target for 2030.
United States	Adopted	Economic incentive	**Low-carbon fuel standard:** Crediting for fuel pathways and projects, based on a carbon intensity score
United Kingdom	Adopted	Economic incentive	**Renewable Transport Fuel Obligation:** Rewards SAF production with the same economic incentives given to road vehicles
Indonesia	Adopted	Mandate	**5% SAF blend mandate:** Target must be met by 2025

18 More SAF Policies are under development

Source: ICAO Global Framework for Aviation Alternative Fuels

Exhibit-9.6: SAF Production Pathways

There are **9** approved pathways available for producing SAF

ASTM Reference	Conversion Process	Abbreviation	Possible Feedstocks	Blending ratio by volume	Commercialization Proposals & Projects
ASTM D7566 Annex 1	Fischer–Tropsch hydro-processed, synthesized paraffinic kerosene	FT	Coal, natural gas, biomass	50%	Fulcrum Bioenergy, Red Rock Biofuels, SG Preston, Kaidi, Sasol, Shell, Syntroleum
ASTM D7566 Annex 2	Synthesized paraffinic kerosene from hydro-processed esters and fatty acids	HEFA	Bio-oils, animal fats, recycled oils	50%	World Energy, Honeywell UOP, Neste Oil, Dynamic Fuels, EERC
ASTM D7566 Annex 3	Synthesized iso-paraffins from hydro-processed fermented sugars	SIP	Biomass used for sugar production	10%	Amyris, Total
ASTM D7566 Annex 4	Synthesized kerosene with aromatics derived by alkylation of light aromatics from non-petroleum sources	FT-SKA	Coal, natural gas, biomass	50%	Sasol
ASTM D7566 Annex 5	Alcohol-to-jet synthetic paraffinic kerosene	ATJ-SPK	Biomass from ethanol or isobutanol production	50%	Gevo, Cobalt, Honeywell UOP, Lanzatech, Swedish Biofuels, Byogy
ASTM D7566 Annex 6	Catalytic hydro-thermolysis jet fuel	CHJ	Triglycerides such as soybean oil, jatropha oil, camelina oil, carinata oil, and tung oil	50%	Applied Research Associates
ASTM D7566 Annex 7	Synthesized paraffinic kerosene from hydrocarbon-hydroprocessed esters and fatty acids	HC-HEFA-SPK	Algae	10%	IHI Corporation
ASTM D1655 Annex A1	Fat, oil, and grease co-processing		Fats, oils, and greases from petroleum refining	5%	
ASTM D1655 Annex A1	Fischer–Tropsch co-processing		Fischer–Tropsch biocrude as an allowable feedstock for petroleum co-processing	5%	Fulcrum

Source: ICAO Global Framework for Aviation Alternative Fuels

DEPLOYING SAF IN INDIA

India is working with sector leaders around the globe to decouple GDP growth from CO_2 and other GHG emissions. Making air travel more efficient could help India achieve this goal. While the aviation industry contributes less than 1 percent of India's total emissions today, it is among the fastest growing sectors of the economy. India is on track to become the world's third-largest aviation market by 2024.

Around the world, more than 360,000 flights have already been powered by SAF. SpiceJet operated India's first domestic biofuel test flight on a 25 percent blend of SAF in 2018. India's Centre for Military Airworthiness and Certification (CEMILAC) piloted SAF use across the Indian Air Force's AN-32 fleet as a milestone toward expanded use in India. Indigo also recently operated its first flight using SAF with a blend of 10 percent SAF and 90 percent conventional ATF in February 2022.

FEASIBLE TECHNOLOGIES IN AN INDIAN CONTEXT

Exhibit-9.7: Comparison of SAF production pathways in an Indian context

1 Alcohol to jet fuel (ATJ)

The ATJ pathway appears to be a better suited pathway for India, considering the availability of feedstock, the possibility to modify existing sugar and ethanol plants, and better commercial viability. The Government of India's E-20 program will also lead to better availability of ethanol. If the number of electric vehicles grows substantially, then surplus ethanol can be diverted to SAF production.

2 Hydro-processed esters and fatty acids (HEFA)

The HEFA route appears to be the more cost-competitive pathway for the widespread adoption of SAF. It uses oil, such as used cooking oil, as feedstock. Due to the limited availability of UCO, the Ministry of Agriculture, Ministry of Rural Development, and state governments may coordinate to promote Tree Borne Oil and short gestation crop cultivation so that the availability of indigenous feedstocks is improved for the production of SAF through HEFA pathway.

3 Gasification / Fisher-Tropsch

It is particularly capital-intensive; although the technology is anticipated to improve over time, even Nth-of-a-kind projects are anticipated to have very high capital costs in the near term.

4 Power to Liquid (PtL)

Power to Liquid (PtL) concept is based on the conversion of renewable energy (RE) to liquid fuels and chemicals such as methanol, oxy-methylene ether (OME), ammonia, and Fischer-Tropsch (FT) products, through production / use of green hydrogen, carbon dioxide and water. It is currently more expensive than any other considered pathway, owing to it being a relatively nascent technology.

Alcohol to Jet (ATJ) appears to be the best suited pathway for India

Source: Deploying sustainable aviation fuels at scale in India World Economic Forum report, June 2021

[6] World Economic Forum, June 2021

[7] ICAO Global Framework for Aviation Alternative Fuels

SAF DEMAND PROJECTIONS

At a 1 percent blending ratio, the requirement of SAF for international aviation would be 100 metric tons per day in India. For domestic aviation, the total SAF requirement would be 300 metric tons per day.

SAF PRICE

SAF is significantly more expensive than conventional jet fuel. Global estimates of the price difference being from two to seven times higher (International Air Transport Association, 2015a; Hollinger, 2020). Since fossil jet fuel is relatively cheaper, shifting to SAF will require the support of government, industry, and consumers, particularly as growth in the Indian aviation market accelerates.

Exhibit-9.8: Impact of increasing sales quantity on cost of production & SAF price

Production cost per metric ton of SAF is expected to vary.

- $1,100 to $1,500 (Rs. 66 - 90 / litre) for HEFA
- $1,200 to $1,600 (Rs. 72 - 96 / litre) for ATJ (sugar streams)
- $1,800 to $2,200 (Rs. 108 - 132 / litre) for ATJ (agricultural residues)
- $1,600 to $2,500 (Rs. 96 - 150 / litre) for gasification / Fischer–Tropsch (municipal solid waste and agricultural residues)

Source: McKinsey Analysis

The price of SAF is also expected to vary.

- ATJ from waste-gas-derived ethanol is the lowest-cost fuel at $660 to $850 per metric ton (39.50 to 51 rupees per litre)

Source: Lanzatech Techno-Commercial Assessment

Photo Credit: Adobe Stock

DELIVERY INFRASTRUCTURE & OPERATIONS

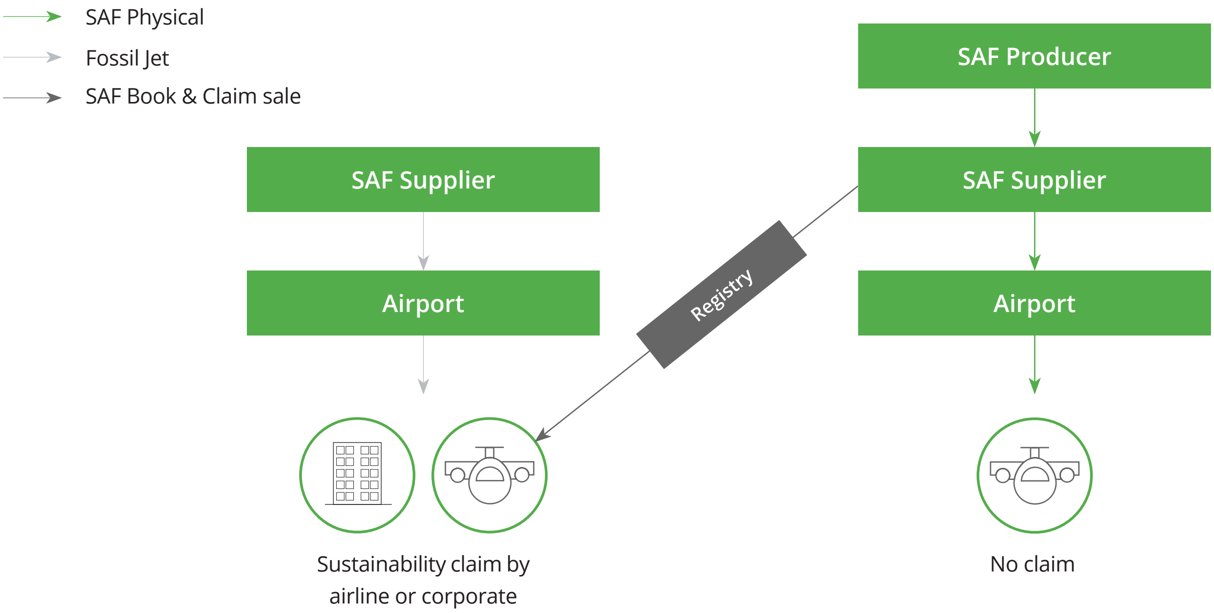
Since SAF is a drop-in fuel, delivery infrastructure will require only minimal adjustments to achieve compatibility, and airport operations are not likely to require any changes. SAF credit accounting can be based on book-and-claim model.

Book-and-claim is a chain-of-custody model in which the administrative record flow does not necessarily connect to the physical flow of material or product throughout the supply chain. RSB, in collaboration with Air BP and other partners including United Airlines and Microsoft, has developed a system for certifying book-and-claim transactions. The airline that purchased the biofuel can claim the CO_2 benefits based on requirements such as proof of procurement, proof of sustainability, and proof of transportation and delivery to the airport. This system will provide benefits such as flexible blend limits and cost optimization (as no new infrastructure will be required).

Exhibit-9.9: The book-and-claim model explained

Methodology	Accounting	Advantages
▪ Virtual Movement of Fuel ▪ No need for buyer & seller to be contacted with physical supply chain ▪ Sustainability attributes can transact independently from sale and transport of physical fuel molecules	▪ RSB (Roundtable on Sustainable Bio-materials) has developed an approach for certification of 'B+C' transactions ▪ RSB is presently working in collaboration with Airbo, United Airlines and Microsoft on 'B+C'	▪ Flexible Blend Limit - Allows airlines to purchase any blend volume of SAF ▪ Cost Optimization - New infrastructure is not required

Exhibit-9.10: RSB's book-and-claim system



Source: https://rsb.org

SAF CERTIFICATION

SAF certification[8] in India is provided by two regulatory institutional bodies: **Centre for Military Airworthiness and Certification** (CEMILAC) and **Directorate General of Civil Aviation**.

- **CEMILAC**, a regulatory body under the Defence Research & Development Organisation. It certifies the air-worthiness of military aircraft, helicopters, aero-engines, and other airborne equipment. CEMILAC has given full clearance to the Indian Air Force to operate all flights using biofuel made by Council of Scientific & Industrial Research–Indian Institute of Petroleum (CSIR-IIP), Dehradun.
- **The Directorate General of Civil Aviation** certifies civil aircrafts. If an SAF producer requires certification on fuel for a test flight, the fuel will first have to meet the requirements of Bureau of Indian Standards' IS 17081:2019 Aviation Turbine Fuel (Kerosene Type, Jet A-1). Subsequently, the producer will require approvals from the Director General of Civil Aviation.

Photo Credit: Adobe Stock

[8] World Economic Forum Report, "Deploying sustainable aviation fuels at scale in India," June 2021

SAF IN INDIA: PROGRESS & RECOMMENDATIONS

PROGRESS MADE

- In India, CSIR-IIP has developed a bio-ATF technology using nonedible vegetable oils, including used cooking oil, as feedstock on a pilot scale.
- August 27, 2018: SpiceJet, a private Indian airline, operated a test flight between Dehradun and Delhi with 25 percent bio-ATF-blended SAF, provided by CSIR-IIP, in one engine.
- CEMILAC has given full clearance to the Indian Air Force to operate all flights using biofuel from CSIR-IIP, including its fleet of more than 100 AN-32 turboprop transportation aircraft.
- The Indian Ministry of Petroleum and Natural Gas has taken the lead to give impetus to the national bio-ATF program to encourage the use of biofuels in the aviation sector. It has proposed a demo plant based on CSIR-IIP technology at the Mangalore refinery.
- December 8, 2021: Indigo signed an agreement with CSIR-IIP to become partners in leading the deployment of SAF in India.
- February 18, 2022: Indigo operated its first flight using SAF, with a blend of 10 percent SAF and 90 percent conventional ATF.
- March 25, 2022: Groupe ADP and GMR Airports signed a memorandum of understanding with Airbus, Axens, and Safranto to conduct a joint study on SAF and its potential in India.

RECOMMENDATIONS

- The HEFA route appears to be the most cost-competitive pathway for the widespread adoption of SAF. Due to the limited availability of UCO, The Ministry of Agriculture, Ministry of Rural Development and State government may coordinate to promote Tree Borne Oil and short gestation crop cultivation so that the availability of indigenous feedstocks is improved for the production of SAF through the HEFA pathway.
- Relevant entities and scientific institutions may focus on R&D of new indigenous feedstocks and processing technologies for efficiency enhancement & achieve economies of scale.
- To overcome initial impetus, the Indian Air Force could provide offtake certainty to guarantee the purchase of initial volumes of SAF for its continuing test flights.
- SAF is costlier compared to conventional ATF. The Government of India can play a major role through various policy support incentives to help address this issue. Viability gap funding, co financing, or tax incentives are required for pilot and demo projects.
- SAF-VGF should be included in “Pradhan Mantri Jaiv Indhan-Vatavaran Anukool Fasal Awashesh Nivaran Yojana” to boost production projects.
- Presently, the goods and services tax applicable on SAF is 18 percent. Because SAF is a green fuel, this tax could be reduced to 5 percent, similar to the tax on ethanol and biodiesel.
- Adopting the book and claim accounting model will reduce the infrastructure cost and transportation-related emissions, specifically in the initial stage when SAF is out of reach for some airlines due to limited production and availability.
- The Government of India can declare a clear mandate for international and domestic airlines to help build up potential demand.

CLEAN SKIES FOR TOMORROW

~20
Organizations from India part of the coalition

100 MN
Target passengers on SAF by 2030

10 %
Target fuel blend by 2030

$2.8 BN
Estimated GDP-eq generated from SAF industry in India

Source: World Economic Forum Report, June 2021

Photo Credit: Adobe Stock

WAY FORWARD

Air travel is growing faster in India than almost anywhere else in the world. The country is predicted to move from the world's eighth-largest user of aviation fuel in March 2019 to the third largest by 2050. Given this expected growth, decarbonizing the sector is very important for India. Early action on this front will also avoid reversing some intermediate moves and regretted expenditures.

Hybrid-electric and hydrogen-powered aircraft could significantly help the industry reach the next efficiency horizon. However, the development and deployment at scale could take 10 to 20 years, and the technology will be initially limited to smaller, shorter-range aircraft.

Producing SAF and blending it with conventional ATF are the immediate options available. This would add to the total volume of jet fuel available in the Indian market, displacing equivalent volumes from imported oil feedstock and thereby supporting the Government of India's vision of self-reliance and the "Make in India" agenda.

Although SAF is significantly more expensive than fossil-derived jet fuel today, costs are expected to fall in the coming decades as technologies mature and the industry reaches economies of scale. By investing early in SAF, India can stay ahead of the technology curve in air mobility.

The SAF industry could be included in an existing framework of biofuel programs that establish minimum off-take agreements, available in the road sector, for example. This would create synergies between producers of biofuels for the road and aviation sectors and build a level playing field of incentives for the participation of state-run oil marketing companies.

Deployment of SAF to decarbonize the sky is the most feasible immediate option available. India can be a hub for SAF production using the ATJ pathway. In addition to meeting its own targets, it can also meet the requirements of other international markets.

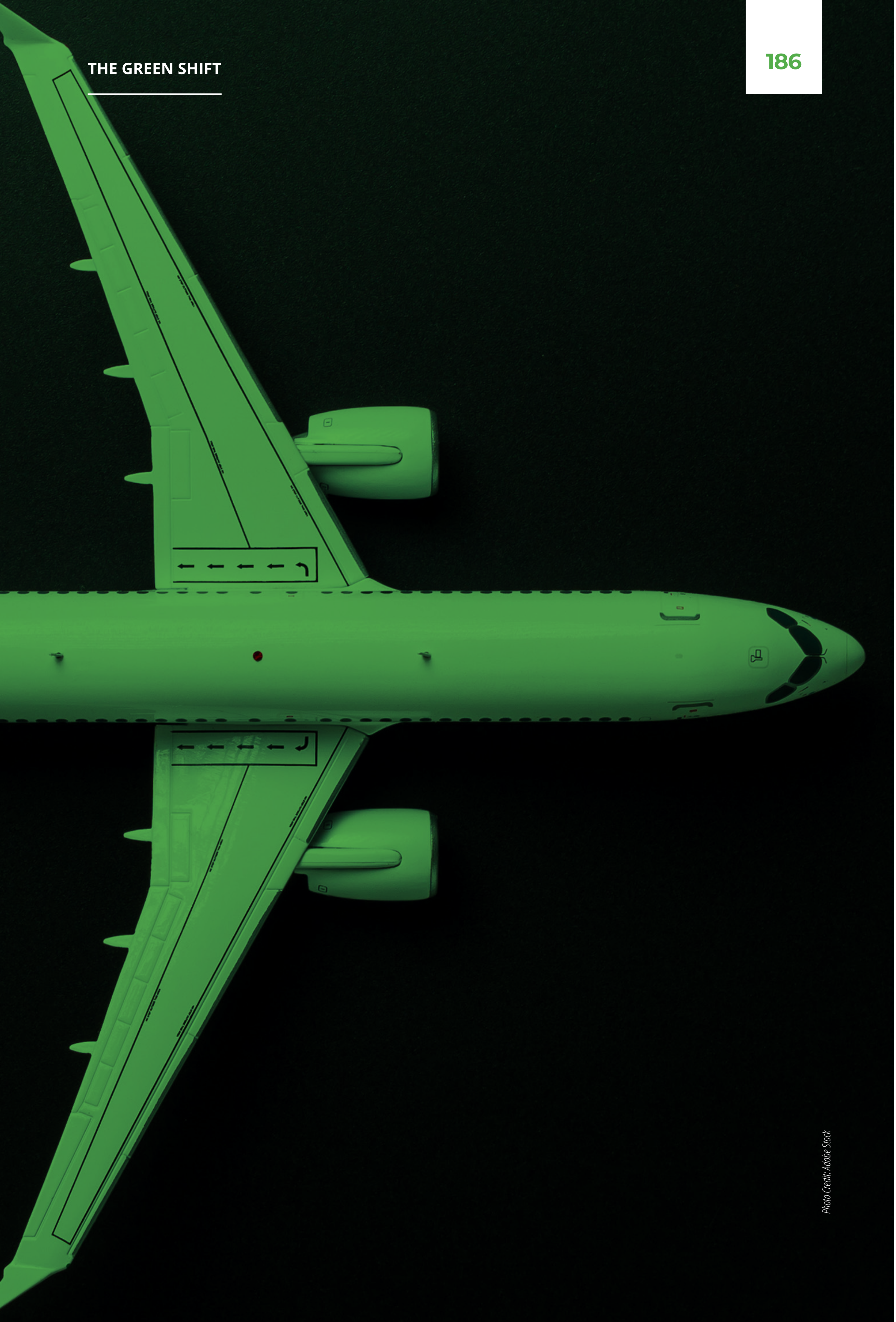


Photo Credit: Adobe Stock

Chapter

10

NATURAL GAS & LNG

In this section

INTRODUCTION

India, currently among the top 13 globally gas-consuming nations, must transition fast from other fossil-based fuels to natural gas to help achieve its climate commitments. It is a well-known fact that carbon emissions from other fossil fuels, such as coal, crude etc., are significantly higher and thus cause global warming, contributing to climate change. Efforts are being made to transition from fossil fuels to sustainable and alternative energy sources towards renewable viz solar, wind, hydro etc. However, to meet the ever-growing zero / low carbon energy demands of a growing economy like India, a substantial increase in clean energy output means wind and energy capacity have to increase by nearly twice the speed of the current pace. This is no mean challenge, as switching towards renewable energy options would be possible only when the core problem of intermittency is addressed. To solve the intermittency issue of renewable energy, gas can play the most influential role besides being a source of meeting low carbon base load energy requirements. Hence despite being a fossil fuel, because of its lower carbon footprint and being an ideal bridge to address intermittency, gas is likely to play a defining role in the transition journey.

0.27 Mn Tons of CO_2 emission per annum

Estimated emission reduction from every 1 MMSCMD of natural gas substituting other polluting fossil fuels

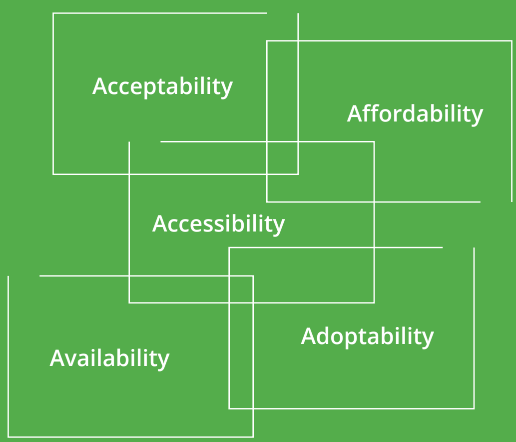
Natural gas can play a decisive role in transitioning to a low-carbon energy system as a transition fuel from fossil fuel to renewable energy sources.[1]

Exhibit-10.1: Role of Natural Gas in India's Energy Transition

Increase the pace at which fast-growing emerging economies reduce their dependency on fossil fuels	Provide low-carbon energy when combined with solutions like carbon capture, use and storage (CCUS)

India's transition from the current ~6% gas in the primary energy mix to 15% by 2030 will require CGD expansion with effective monitoring, faster expansion of the gas pipeline network, focused LNG adoption across sectors, sufficient availability of LNG and creation of strategic gas storage reserves.

5 A's to transition from existing fuel mix to clean fuel mix



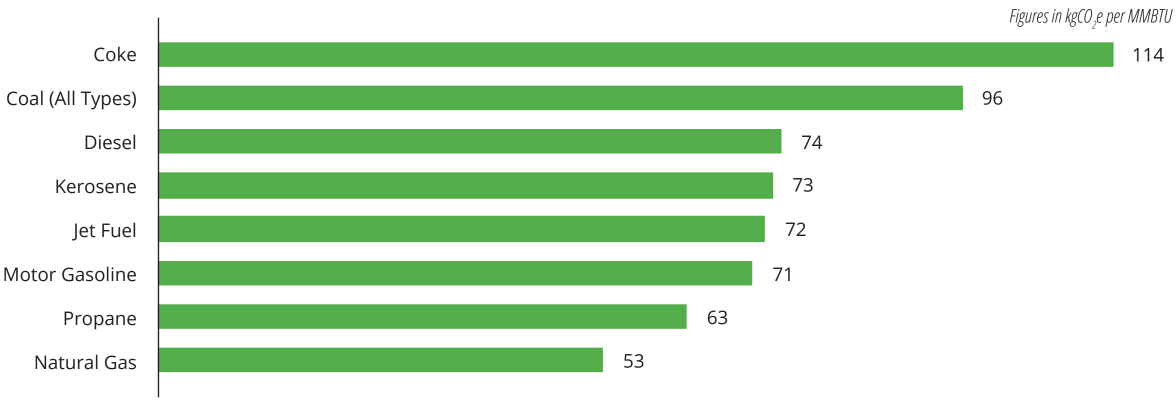
[1] BP Energy Outlook, 2022

TRANSITIONING TO A GAS ECONOMY

'A' – ACCEPTABILITY: LOWER CARBON EMISSIONS AS COMPARED TO OTHER FOSSIL FUELS

Consistent efforts are being made to reduce GHG emissions worldwide. In this context, the standard norm for acceptability of the transition fuel requires that the carbon emissions of the new/transition fuel should be less than the existing fuel for the same amount of energy consumed. The specific carbon emissions from different fossil fuels in terms of kg of CO2 emitted per Million Metric British Thermal Units (MMBTU) are as shown in Exhibit 10.2.[2]

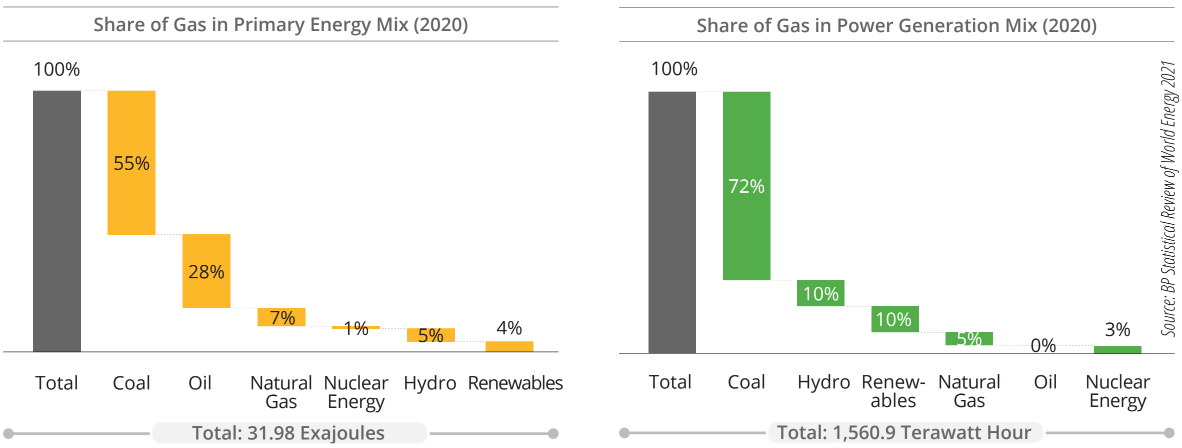
Exhibit-10.2: Specific Carbon dioxide emission from various fuels



Source: https://www.eia.gov/environment/emissions/co2_vol_mass.php

It is evident from the above graph that Natural Gas has the lowest emission levels as compared to other fossil fuels. It produces only around half the carbon dioxide (CO_2) and just one-tenth of the air pollutants of coal. Presently, gas accounts for ~6% of India's energy mix which remains coal-dominated. This has impacted the achievement of profound decarbonization objectives of the country. The Government has recognized this issue and has adopted a multi-pronged approach towards promoting diversification of the primary energy mix with lower carbon-emitting energy sources (IEA 2020). India aims to become a natural gas-based economy by increasing its gas share to 15% of the primary energy mix by 2030. The International Energy Agency (IEA) predicts India's natural gas share to be 11-15% by 2040 as the country is moving towards cleaner energy sources in a shift away from coal and petroleum, under its climate commitment to become a net zero carbon emissions nation by 2070. Exhibit-10.3 graphically depicts the share of gas in India's primary energy and power generation mix.

Exhibit-10.3: Share of Gas in India's primary energy mix and power generation mix



In terms of transportation, natural gas is transported through pipelines right from the source point to the consumption point, which has lower carbon emissions for the same amount of energy transported for the same distance as compared to other transportation modes such as trucks, rail, aviation, LNG, other mode of gas transportation, also has lower overall carbon footprint. This is apart from the fact that pipelines are the safest mode of transportation. These factors make natural gas the best fit to act as a bridge fuel in transitioning towards cleaner energy sources like renewables and green hydrogen. Hence, transitioning to natural gas shows enormous potential to reduce near-term CO_2 emissions and air pollution.

'A' – AFFORDABILITY: CHEAPER FUEL

Society would more readily and rapidly accept cleaner fuel if the given fuel were more cost-effective and cheaper than the existing fuel. On this count also, natural gas scores high as a transition fuel, especially in the Compressed Natural Gas (Transport) and Piped Natural Gas (Domestic) segments (barring the ongoing price surge which should be treated as an off-shoot of exceptional circumstances).

Traditional cooking fuels like firewood, coal, cow dung cakes etc., have detrimental impacts on health and the environment. Accordingly, in May 2016, MoP&NG introduced the flagship - 'Pradhan Mantri Ujjwala Yojana' (PMUY)[3] scheme with the objective to provide 8 crore LPG connections to households belonging to the society's marginalized & economically deprived sections. The Government also provided cash assistance for LPG connections along with the first LPG refill and Stove free of cost. With this scheme, a section of society has transitioned from highly polluting and unhealthy fuels to a cleaner fuel, Liquefied Petroleum Gas (LPG). To meet the increasing demands, India is still mainly importing LPG.

Table-10.1: LPG Import Quantity & Cost

	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21
LPG Import in Million US$[4]	6,144	5,955	3,922	4,775	5,849	7,178	7,070	7,242
LPG import quantity in TMT[5]	6,567	8,313	8,959	11,097	11,380	13,235	14,809	16,476

Introduction of PMUY

At the same time, it is essential to analyze the base price of the alternate fuel. In 2013[6], MoP&NG had notified guidelines for the allocation of domestic natural gas to City Gas Distribution (CGD) entities for CNG (transport) and PNG (domestic). The guidelines were subsequently revised in 2014[7] and further revised in 2022[8]. MoP&NG has approved the allocation of domestic APM/NAPM natural gas to cater to CGD entities' demand at a Uniform Base Price for use in CNG (Transport) and PNG (Domestic) segments. However, the delivered price of domestic gas to individual CGD entities for CNG (Transport) and PNG (Domestic) may vary on account of transportation charges and local taxes and duties. Further, MoP&NG had notified New Domestic Natural Gas Pricing Guidelines in 2014[9], under which the Director General of Petroleum Planning and Analysis Cell (DG PPAC) shall notify the prices of APM / NAPM Natural gas as well as prices of Ultra-Deepwater Areas, Deep Water Areas and High-Pressure High-temperature (HPHT) gas on US$ per MMBTU on half yearly basis. The notified prices are as shown in Table 10.1.

[3] *https://www.pmuy.gov.in/about.html*

[4] *MoP&NG, Economic & Statistics Division, Indian Petroleum & Natural Gas Statistics 2017-18 & 2020-21*

[5] *Ibid as Footnote no. 4*

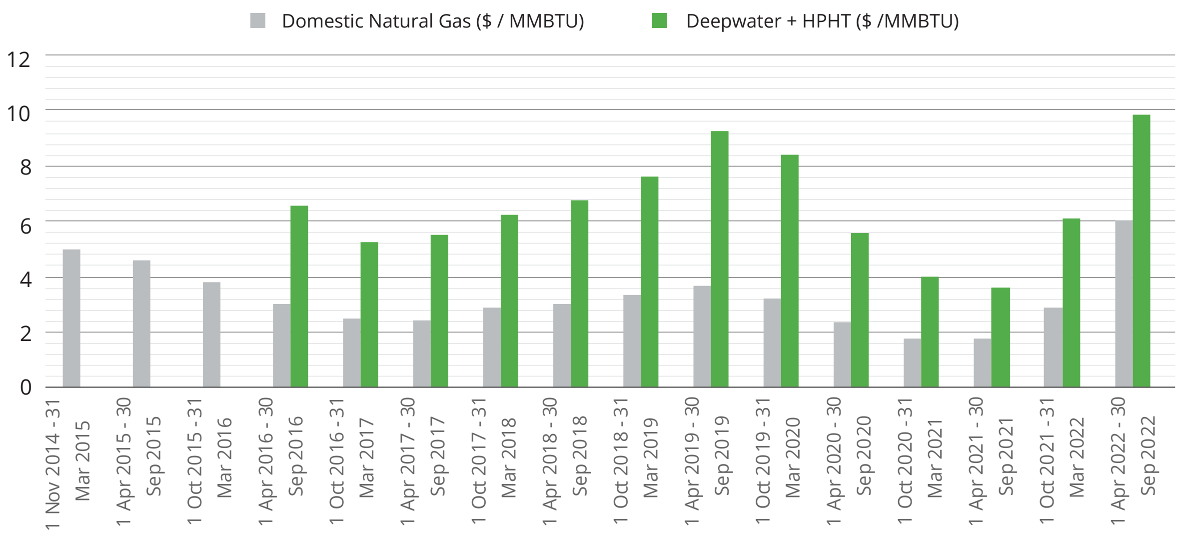
[6] *MoP&NG OM no. L-16013/3/2012-GP-II dated 14.11.2013*

[7] *MoP&NG OM no. L-16013/3/2012-GP-II dated 03.02.2014 & L-16013/3/2012-GP-II dated 20.08.2014*

[8] *MoP&NG OM no. L-16016/3/2020-GP-I-Part(1) (E: 42577) dated 06.05.2022*

[9] *MoP&NG Gazette notification no. 22011/3/2012-ONG.D.V dated 10.1.2014*

Exhibit-10.4: Notified APM/NAPM and Deep water + HTPT prices ($/MMBTU)



MoP&NG in the notified allocation guidelines has provided for meeting the increasing demand from imported LNG and, as such, approved pooling of domestic APM/NAMP natural gas with MDP/RLNG/Spot/Biogas for meeting the requirement of CGD entities at Uniform Base Price. The average price (5-year average) of imported LPG lands at around US$10-12/MMBtu, whereas the average imported price of LNG is US$6-9 /MMBtu, suggesting that LNG import is cheaper than LPG. Given the global geopolitical crisis, LNG prices have been hovering in the high thirties, which is a very anomalous situation. Over the long term, except for the anomaly witnessed in the market today, gas prices have tended to be lower than crude in calorific value terms. The market hopes this to reverse in the long term as the ongoing crisis gets settled or subsides.

Imported LNG has generally been cheaper than imported LPG and domestic & HPHT gas is more affordable than imported LPG on a base price basis. Uniform Base prices for the last three cycles are 8.04 $/MMBTU for the 2nd Fortnight May 2022, 8.05 $/MMBTU for June 2022 and 8.91 $/MMBTU for July 2022. Considering this trend, it is expected that prices for natural gas may be higher than alternative fuels, which will hamper the transition. Certain short-term aberrations are possible in the future, in view of the different time periods for which base input prices are considered for working out gas prices in India vs the LPG prices, which reflect the prevailing international prices with minimal lag. Considering the highly dynamic market, the domestic gas pricing policy, as notified in 2014, may be reviewed regularly to ensure that PNG (domestic) prices remain affordably below LPG prices to incentivize the transition to cleaner fuel. Also, to ensure more synchronous movement across different energy sources, the gas prices reference period needs to be curtailed.

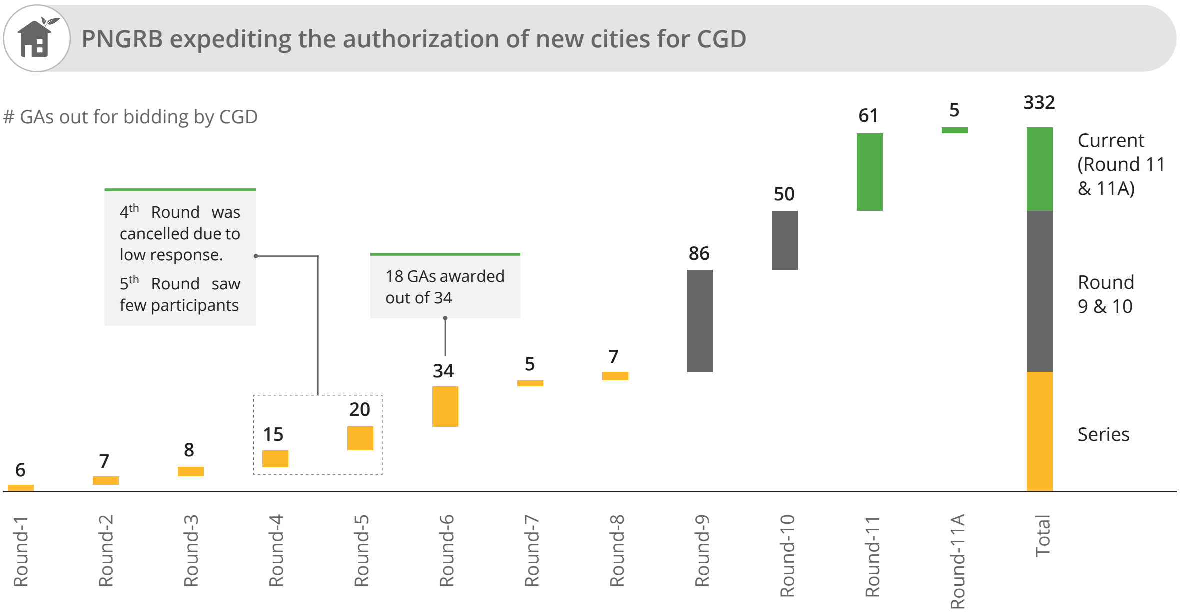
It may be noted that currently, LPG is under the GST regime, whereas natural gas is out of the purview of GST. As such, tax on these products may lead to different landing prices at the consumer end, which needs further attention. While there is an urgent need to bring all fuels within the GST regime, at least natural gas may be immediately considered to be brought under the GST purview and taxes should be levied in such a manner that the landing price at the customer end is cheaper as compared to alternate fuels. This will help in the transition to a lower carbon emission economy.

'A' – ACCESSIBILITY: INFRASTRUCTURE DEVELOPMENT

In India, the development of the National Natural Gas Grid began with the commissioning of the Hazira - Vijaipur - Jagdishpur (HVJ) pipeline in 1987 to supply gas to fertilizer plants in Uttar Pradesh. As of 1st April 2019, a 16,324 km natural gas pipeline is operational, and more than 15,000 km is under construction, spread across the length and breadth of the country. It has enabled the growth of City Gas Distribution (CGD) to supply CNG and PNG. CGD activities started around 1992 in India and have rapidly expanded to many Geographical Areas (GAs).

In 2006, the Government of India passed the Petroleum and Natural Gas Regulatory Board (PNGRB) Act to establish PNGRB. PNGRB has formulated Petroleum & Natural Gas Regulatory Board Regulations, 2008 (Authorizing Entities to Lay, Build, Operate or Expand City or Local Natural Gas Distribution Networks). PNGRB authorized entities to lay, build, operate or expand city or local natural gas distribution networks. PNGRB has held 11 bidding rounds of Geographical Areas (GAs) under its 2008 Regulations, providing the necessary impetus for expanding the CGD network and increasing gas usage. In 2022, the 11A bidding round was held, adding five more GAs to the overall list of 328 GAs covering 538 districts spanning 88% of the geographical area and 98% of the population. Exhibit 10.5 elucidates the year-wise details of Gas authorized in India.

Exhibit-10.5: Year-wise details of GA authorized in India



CGD: City Gas Distribution

GAs: Geographical Areas

Source: PNGRB / Press Search / BCG Analysis

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[10] *https://en.wikipedia.org/wiki/HVJ_Gas_Pipeline#:~:text=The%20project%20was%20started%20in,grid%20was%20commissioned%20in%201987.*

[11] *https://www.ppac.gov.in/content/154_1_PipelineandCGDStructure.aspx*

[12] *https://www.pppinindia.gov.in/infrastructureindia/web/guest/project-list?p_p_id=projectlist_WAR_Projectportlet&p_p_lifecycle=0&p_p_state=normal&p_p_mode=view&p_p_col_id=column-1&p_p_col_count=1&_projectlist_WAR_Projectportlet_jspPage=%2Fhtml%2Fprojectlist%2Fview.jsp&_projectlist_WAR_Projectportlet_searchName=&_projectlist_WAR_Projectportlet_searchType=Sub+Sector&_projectlist_WAR_Projectportlet_id=53&_projectlist_WAR_Projectportlet_projectTypeeids=&_projectlist_WAR_Projectportlet_authorityName=&_projectlist_WAR_Projectportlet_isShowAllTerminatedProjects=true&_projectlist_WAR_Projectportlet_cur=1&_projectlist_WAR_Projectportlet_delta=75&_projectlist_WAR_Projectportlet_keywords=&_projectlist_WAR_Projectportlet_advancedSearch=false&_projectlist_WAR_Projectportlet_andOperator=true&_projectlist_WAR_Projectportlet_orderByCol=status&_projectlist_WAR_Projectportlet_orderByType=asc*

[13] *PIB, Press Release dated: 10.02.2022, As on 31.12.2021, 3628 CNG stations have been commissioned across the country.*

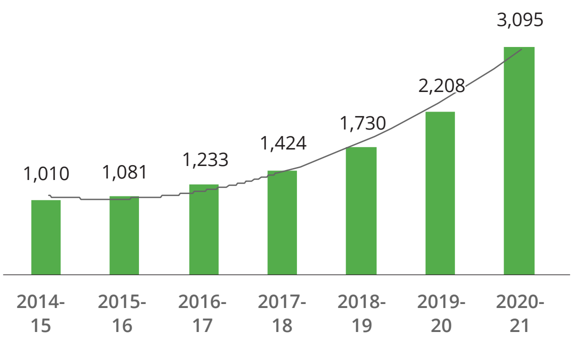
The expansion of CGD through multiple GA rounds across geographies has helped grow CNG and PNG connections in India.

Exhibit 10.6 below lists the total number of PNG and CNG stations across the country between the year 2015 and 2021.

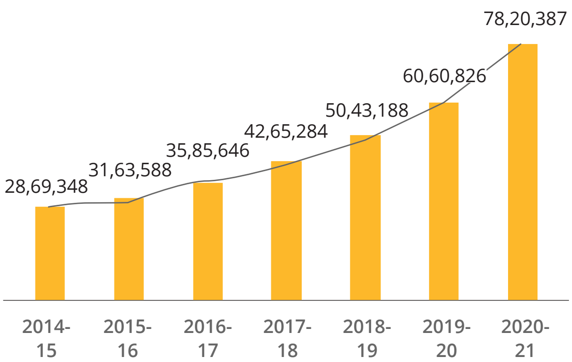
Exhibit-10.6: Year-wise CNG station and PNG connection across India

Year	No. of CNG Stations	No. of PNG connections		
		Domestic	Commercial	Industrial
2015	1,010	28,69,348	22,356	5,918
2016	1,081	31,63,588	23,304	6,225
2017	1,233	35,85,646	21,996	6,670
2018	1,424	42,65,284	26,131	7,601
2019	1,730	50,43,188	28,046	8,823
2020	2,208	60,60,826	30,617	10,256
2021	3,095	78,20,387	32,339	11,803

Number of CNG Stations



Number of PNG Connections



Digitalization is an emerging trend that offers opportunities throughout the CGD value chain. From demand management to improving operational resilience, remote condition monitoring to real-time customer communication and new technologies and data analytics provide multiple digitalization adoption avenues for CGD firms to achieve specific business goals while maximizing efficiency. Regulation 2008 has provisions for online monitoring of the progress of the MWP submitted by the authorized entity. An online system or mobile App may be developed to monitor the real-time progress of CGD entities, wherein the relevant data related to the progress of DPNG connections and CNG stations in each GA may be submitted by CGD entities at regular intervals. It would enable real-time data monitoring that will help improve transparency and tracking of the progress of all CGD entities.

Entities often face various hurdles when setting up distribution networks, especially with respect to land acquisition. Appropriate land acquisition or purchase from a suitable person has always remained challenging. The district administration may create a pool of land that can be provided for setting up the CNG stations. Further, different models are being adopted for installing the CNG stations, such as – Company Owned Company Operated (COCO) and Dealer Owned Dealer Operated (DODO) models, wherein DODO is prominent. In the DODO model, the entire investment in the range of crores of rupees is made by the person providing the land. For the CGD network to expand to tier-2 and tier-3 locations, there is the possibility that the owners of appropriate land may not be financially sound to be capable of making investments. Accordingly, new and innovative approaches are required to match land availability with financial capabilities. A hybrid model may be introduced wherein land will be provided by the dealer, equipment and other investments will be made by the company, and the outlet is to be operated by the dealer. Alternatively, financial incentives may also be introduced for equipment and other machinery.

A few other challenges also need to be looked into. India's growth is broad-based, i.e., spread over large geographical areas across different regions. Some areas have lower demand density that does not meet the minimum anchor load requirement, hindering network expansion owing to low returns. In India, we have seen that the development of the National Gas Grid and CGD network played a vital role in connecting the consumption centers with the supply points. However, the development of the National Gas Grid has a long gestation period. In such a scenario, alternative options, such as skid-mounted CNG trucks, are being utilized. With the advancement of technology, Small Scale Liquefied Natural Gas (SSLNG) technology can play a crucial role in bridging the gap left by National Gas Grid and CGD network. In locations where National Gas Grid is still developing or the remote locations that would be unserved by conventional natural gas infrastructure, the SSLNG technology enables flexible supply chains to deliver to multiple smaller distributed users. LNG can be transported by road into skid-mounted storage or train to the point of use, providing flexibility to deliver LNG at the targeted locations.

Draft LNG Policy 2021[14], by MoP&NG, talks about creating a Virtual Pipeline by transporting gas through rail and LNG trucks to industries. As the National Gas Grid develops over time, the virtual pipeline may be replaced by the physical pipeline, and the setup may be shifted to other places for minimizing and efficient investment management over the life cycle. It may be noted that the volume delivered through cascade-mounted CNG trucks is small, increasing transportation costs and detrimental to the environment because of the higher carbon footprint. However, SSLNG can deliver LNG up to 1 million metric tons per annum (MMTPA), equivalent to around 3.6 million metric standard cubic meters per day (MMSCMD)[15] of Natural Gas. Such volumes are sufficient to supplement the CGD requirements of gas which are currently un-serviced by pipelines. This approach can deliver the required volume in a lesser number of transits reducing the transportation cost and carbon emissions. Therefore, critical analysis among alternatives of LNG virtual pipeline, NG Virtual Pipeline vs Physical Pipeline may be done, which could serve as a guide for planning the optimum infrastructure for providing natural gas accessibility. Preferred options could be different for different locations.

[14] MoP&NG F No. L-12018/7/2016-GP-I (E:35893) dated 17.02.2021

[15] https://gailonline.com/BVNaturalGas.html - Energy conversion matrix

'A' – 'ADOPTABILITY': SWITCHING TO CLEANER FUEL

With GDP growth, freight transportation by road might increase. As such, innovative solutions are required against two competing but equally desirable objectives of reducing road transportation as much as possible as well as GHG emissions. In line with the draft LNG policy 2021, LNG should be pushed as auto fuel, and heavy-duty trucks should be converted into LNG trucks. It is estimated that around 87% of diesel sales are in the transport segment, with trucks and buses accounting for about 68% of diesel sales in the country[16]. While, at the moment, it seems easier to convert diesel trucks to CNG trucks, however, there are limitations. LNG overcomes the CNG's limitation of being used for shorter distances and lower tonnage carrying capacity.

Further, LNG has a higher calorific value than diesel, which means trucks can travel longer distances with the same fuel quantity[17]. Notably, emissions from LNG are much lower than those from diesel and can help reduce GHG emissions. For the same, thrust must be put on companies to push for fleet conversion. To start with, government entities may consider converting fuel delivery trucks to run on LNG fuel.

At the same time, the chicken-egg dilemma resolution is vital between 'adoptability' and accessibility. Therefore, accessibility of LNG fuel is critical for such adoption. To achieve this, the draft LNG policy 2021 aimed to establish LNG dispensing stations on identified highways. Further, it was estimated that three states – Uttar Pradesh, Maharashtra and Haryana[18] contributed nearly 40% of the diesel sale in India.[19] Similarly, LNG dispensing stations can be set up in high diesel-consuming states to cater to intra-state transportation needs. Additionally, companies undertaking fleet conversion might set up LNG dispensing stations near their premises. All these efforts may create the required ecosystem for switching to this cleaner fuel.

'A' – AVAILABILITY: SUPPLY OF GAS

The demand for natural gas is expected to increase in emerging economies like India due to industrialization . Both domestic production and imports ensure the supply of natural gas in India. Natural gas production in 2020 was 85+ Million Metric Standard Cubic meters per Day (MMSCMD). About 84.67% of this domestic gas production is by ONGC and OIL from the nomination regime. The remaining 15.33% of natural gas production was by Private / JV companies from the PSC regime. Exhibit-10.7 outlays the domestic natural gas production by company ownership.

Over the last decade, India's natural gas sector has been impacted by the reduced availability of low-priced natural gas owing to a decline in domestic gas production and the costly option of imported LNG. Over the last decade, LNG imports have steadily increased to reach about 55% in the financial year 2021. Exhibit 10.8 depicts the increased share of LNG imports to India over the last decade. By 2030, dependency on LNG / imports is expected to rise even more. The import forecast has been carried out by various agencies like NITI Aayog, BCG, British Petroleum and

[16]All-India study on sectoral demand for petrol & diesel report -https://www.ppac.gov.in/WriteReadData/Reports/20220329120600202909ExecutiveSummarySectoralConsumptionStudy.pdf

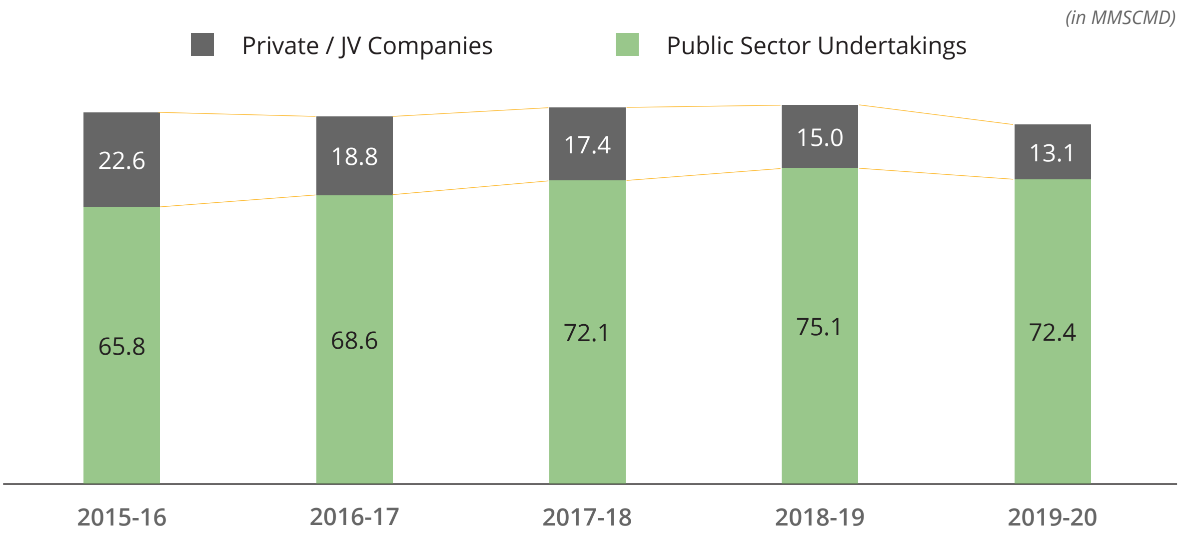
[17] https://www.forbesindia.com/blog/economy-policy/why-trucks-should-consider-switching-to-liquefied-natural-gas-lng/

[18] Ibid as Footnote no. 23 (Crisil report)

[19]Ibid as Footnote no.1 - BP Energy Outlook, 2022 edition

Photo Credit: Adobe Stock

Exhibit-10.7: Natural Gas production by Company Ownership



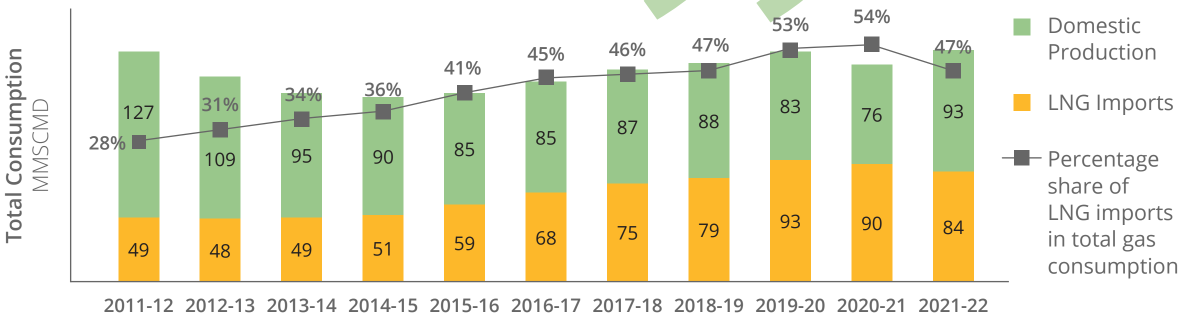
Source: Ministry of Petroleum & Natural Gas; Economic Times; Petroleum Economist

PNGRB, with LNG import growth ranging from 4.3% to 12%. Exhibit-10.9 lays out the scenario-wise projected CAGR for import growth.

The price of LNG is a significant concern for the government and commercial buyers. Prices of spot LNG have never been more volatile. They have ranged from as low as US$1.8 per MMBtu in April 2020 to highs touching even US$50 per MMBtu during the recent past. India's LNG contracts are mostly linked to crude oil indexes like Dated Brent Crude, Japan's Crude Cocktail, US Henry-hub and others. Besides reducing geopolitical risks, diversification in the sourcing portfolio also reduces supplier negotiation power. Considering demand forecast in other markets, net zero emission targets and pressure exerted from the other cleaner fuels such as hydrogen, biofuels, renewable energy etc.; it is expected that demand for LNG may decline in the rest of the world over the medium term, though the current global geopolitical crisis has made LNG as the only hope for Europe to be able to meet even its rationed energy needs.

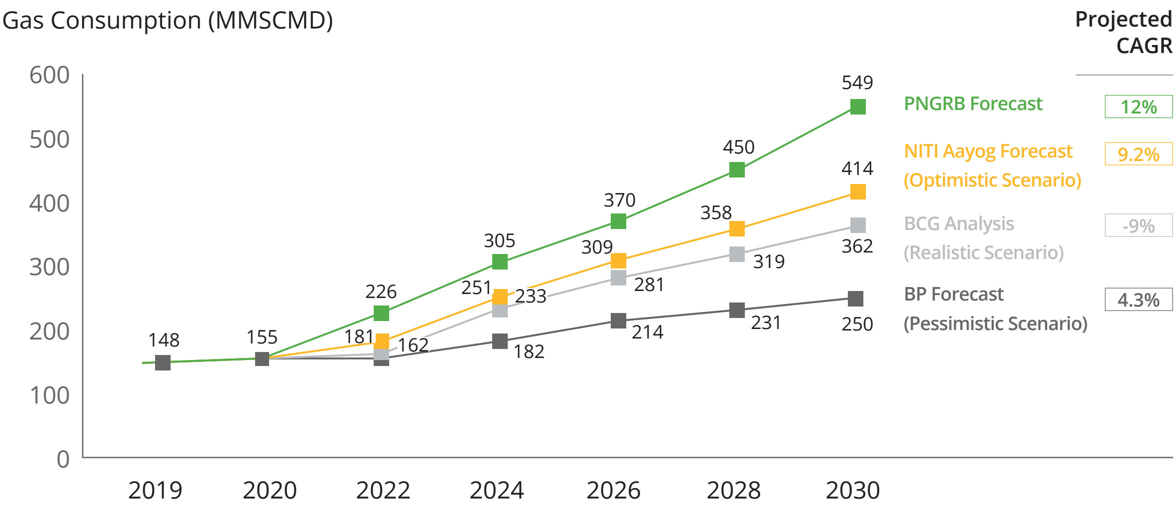
Exhibit-10.8: India Gas Consumption split by domestic & imported gas, 2011-22

Share of LNG imports has been increasing over the past decade, reaching ~55% in FY21.



Source: Petroleum Planning and Analysis Cell

Exhibit-10.9: India's gas demand forecast with projected growth in dependency on LNG / imports



148-156	159-167	173-186	230-247	269-290	310-329	340-367	Demand in MMSCMD (Consensus Estimates)
50-55%	50-55%	55-60%	55-60%	60-65%	60-65%	65-70%	Share of LNG (%)

OPTIMISTIC SCENARIO

- Revival of gas power to support peaking load and RE integration
- New CGDs operative by 2022
- Petrochem investment target is met
- Fertilizer imports substituted

REALISTIC SCENARIO

- Domestic gas for peaking power demand
- New CGDs to operate from 2023
- 50% petrochemical investments expected operational on-time

PESSIMISTIC SCENARIO

- CGDs launch pushed to 2024
- Status-quo in gas power (with 30% PLF)
- Significant drawdown / delay (-75%) in planned petrochem investments

Source: Niti Aayog; British Petroleum; PNGRB; BCG Analysis

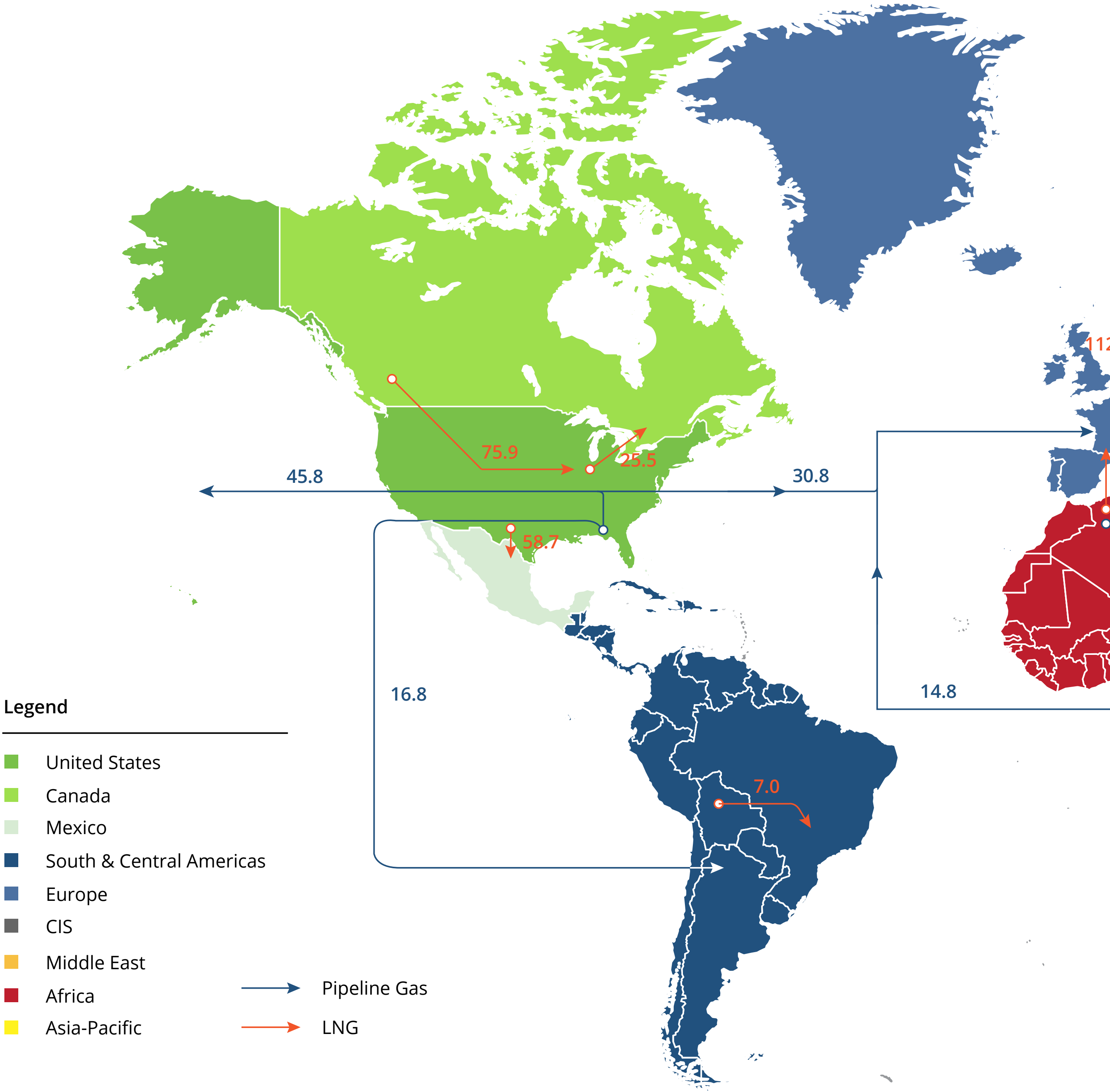
Accordingly, India should be able to leverage its buying position as the impact of the ongoing crisis recedes. This provides India with an opportunity to negotiate the terms of LNG contracts by developing its own index as the market reaches maturity. The development of such an index may also help mitigate the volatility in LNG prices.

There are 20 major LNG exporting countries globally, though the number of LNG importing countries, currently above 40, is steadily increasing. Exhibit-10.10 depicts the world LNG trade movement.[20]

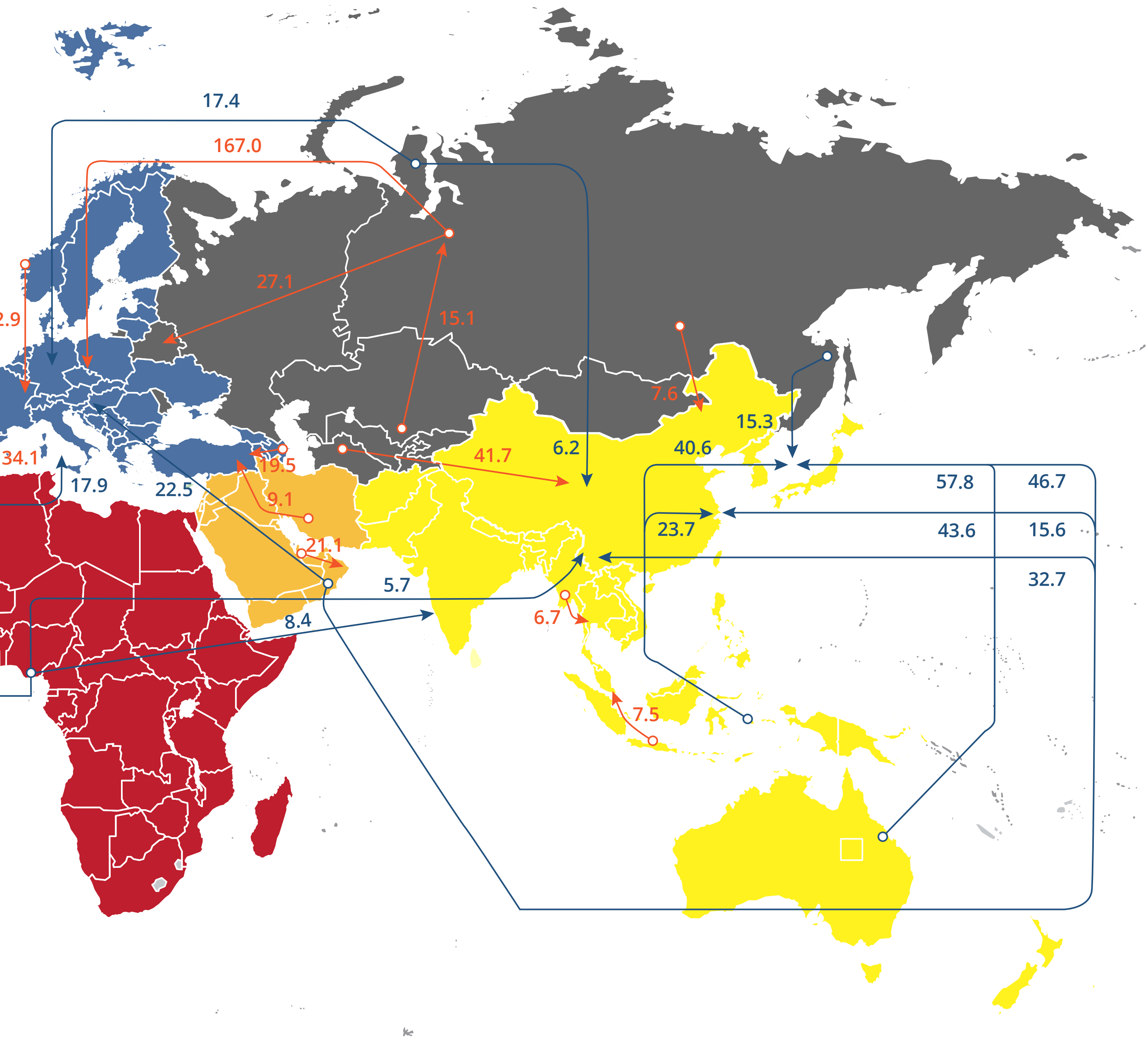
In India, majority of the LNG is currently imported from Qatar, Russia, US and Australia. Other countries exporting gas to India are Oman, UAE, and Angola. India may consider further diversification of its LNG import portfolio to cushion the impacts of uncertainties, thereby mitigating the volatility in prices and reducing supplier risk. These capacities will be sufficient for the LNG portfolio. Accordingly, actions must be taken to develop LNG terminals in the eastern and western regions to cater for imports from around the world.

[20] *BP Statistical Review of World Energy 2022*

Exhibit-10.10: Major Natural gas (Pipeline + LNG) trade movement in 2021



The draft LNG policy 2021 by MoPNG aims to create a regasification capacity of 70 MMTPA by 2030 and 100 MMTPA by 2040. The policy also aims at developing common carrier capacities in LNG terminals. These terminals are envisaged to be created along India's eastern and western coasts. India needs to create a free and competitive regasification market, including on-shore and



off-shore facilities, to meet the LNG needs of all areas, including A&N and Lakshadweep. Hence, draft LNG policy must be notified at the earliest and further developed action plans along with the recommendations need to be provided by the present committee.

Table-10.2: Existing LNG Terminals

S. No.	Existing Re-Gas Terminals	Promoters	Capacity (MMTPA)
1	Dahej (Gujarat)	Petronet LNG Ltd.	17.5[#]
2	Hazira (Gujarat)	Shell Energy India Pvt. Ltd	5.2
3	Mundra (Gujarat)	GSPC LNG Ltd.	5
4	Dabhol (Maharashtra)	Konkan LNG Ltd	5 (2.9*)
5	Kochi (Kerala)	Petronet LNG Ltd	5
6	Ennore (Tamil Nadu)	Indian Oil LNG Pvt Ltd.	5
	Grand Total		**39 MMTPA**

** Further expanding capacity to 22.5 MMTPA.*
*** To be increased to 5 MMTPA on completion of Break Water.*

Source: Petroleum Planning and Analysis Cell; Petronet LNG Ltd; Press Search

Table-10.3: Proposed / Upcoming LNG Terminals

S. No.	Proposed / Upcoming Re-Gas Terminals	Terminal Promoter	Re-gas Capacity (MMTPA)
1	Jafarabad (Gujarat)	Swan Energy	5
2	Jaigarh (Maharashtra)	H-Energy	3-4
3	Kakinada (A.P.)	GAIL and AP govt.	3-5
4	Karaikal (A.P.)	Atlantic Gulf & Pacific	1
5	Dhamra (Oddisa)	Adani	5
6	Chhara (Gujarat)	HSEPL (Subsidiary of HPCL)	5
7	Dahej Expansion (Gujarat)	Petronet LNG Ltd.	5
8	Gopalpur (Odisha)	Petronet LNG Ltd.	4-5
	Grand Total		**~31 MMTPA**

Source: Petroleum Planning and Analysis Cell; Petronet LNG Ltd; Press Search

COAL GASIFICATION

With its coal reserve of 307 billion tons, India uses about 80% of it for power generation. Presently coal forms ~55% of India's total energy mix. With the rising environmental concerns, the Ministry of Coal is considering the diversification of coal for its sustainable use. In this regard, NITI Aayog has prepared a "National Coal Gasification Mission" to achieve a 100 MT capacity of coal gasification by 2030. The mission documents outlay the availability of coal, type of gasifier, cleaning of gas and other necessary details. Coal gasification is considered a cleaner option compared to burning coal. BHEL has developed technology to convert high ash Indian coal into methanol. Syngas production is an intermediary step of the process; thereby, the process can also be utilized to create synthetic natural gas. Although coal gasification can be a potential source of energy, however, based on current technologies, it is a capital and energy intensive process. Taking note of the same, several incentives have been provisioned in the Mission, of which Viability Gap Funding is the most prominent one. It is estimated that around 10 Giga-calorie of energy is consumed in producing a ton of urea through coal gasification compared to 5 Giga calories of energy consumed in producing per ton of urea from natural gas. Accordingly, it is a carbon-intensive process. Therefore, coal gasification to create synthetic natural gas from vast amounts of high ash coal available in India would be a real success if either lower energy-intensive technology is developed or the energy utilized is green with the necessary policy support.

STRATEGIC STORAGE RESERVE

India needs to build strategic gas storage reserves to fill the large gap between the projected consumption of natural gas and domestic consumption. This will strengthen the country's energy security and shield it from disruptions and associated price fluctuations. Presently, India doesn't have any strategic gas reserves. India has strategic oil storages with a capacity of 5.33 MT at Vishakhapatnam (1.33MT), Mangalore (1.5MT) and Padur (2.5MT) and can serve India's crude oil requirement for ~9 days. In addition, two additional storage reserves are proposed at Chandikol and Padur under public-private partnership mode.

Worldwide, countries have understood the importance of underground storage reserves (UGS) and are continuously undertaking such UGS development projects. Worldwide, as of 2019, there were more than 650 operational UGS facilities with a gas storage capacity of 422 billion cubic meters (BCM). Present UGS facilities, spread across North America, Europe, CIS (Commonwealth Independent States), Asia-Oceania, and the Middle East (mostly Iran).

Around 80% of the global working gas storage happens in depleted fields and ~20% in salt caverns. India may consider establishing UGS facilities using depleted oil & gas fields of national oil companies, salt caverns and aquifers. In addition, these storage facilities are to be chosen close to pipeline infrastructure for the ease of use. Needless to mention that these storages have no commercial viability but are of national importance and would require substantial funding. These depleted storages can be offered on a competitive basis to interested gas marketers. Overseas gas producing companies may also be offered a stake in such storage. Policy support is required in this matter.

Thus, gas will help abate the carbon footprint of electricity for the commercial and industrial sectors. Gas usage could also eventually help transition towards the hydrogen economy by using the same infrastructure, subject to technical feasibility, to deliver hydrogen mixed gas which can provide early support to hydrogen growth. To displace coal and other higher carbon-emitting fossil fuels for hard-to-abate industrial sectors, gas usage needs to be promoted. Gas can help meet increasing Indian energy demand pushed by tail-winds of increasing population, industrialization, and growing prosperity.

Table-10.4: Global Strategic Gas Storages

Region	UGS	Working Gas Capacity (BCM)	Deliverability (MCM/D)
North America	441	163	3,726
Europe	141	108.6	2,082
CIS	47	121	1,242
Asia Oceania	28	22.4	200
Middle East	3	6.9	34

Source: CEDIGAZ – Natural Gas Information

KEY RECOMMENDATIONS

The transition journey across different parts of the world could require the adoption of situation-specific unique solutions. For India, with its vast shoreline and proximity to some of the prolific gas-producing regions and also to build multiplicity of sources of energy supply, gas can play a crucial role, especially to decarbonize hard-to-abate industrial and transport sectors. Indian investments in expanding the gas grid and coverage of nearly the entire population through CGD make gas an ideal choice. This will also ensure effective utilization of the existing investment besides helping achieve emission reduction targets.

NATURAL GAS TO SERVE AS A TRANSITION FUEL

Natural gas is best suited to play a role in the transition to a low-carbon energy system as a transition fuel from conventional hydrocarbon fuel to renewable energy sources. However, the long-term vision is to switch entirely to renewable energy sources. It is worthwhile to note that switching to renewable energy options would be possible only if the energy storage solutions are commercialized to solve the intermittency issue of renewable energy. India has aspirations to increase the share of natural gas in the energy basket to 15%, which will help create an ideal foil for desired growth of renewables as a solution to intermittency. On the way to the net zero objective, natural gas can play a critical role as a transition fuel, with its share in the energy mix rising over the next 25-30 Years.

USE OF DIGITAL TECHNOLOGY TO PROVIDE IMPETUS TO EXPAND CGD NETWORK

A country-wide common digital portal may be established to monitor the Minimum Work Program (MWP) of CGD entities at the time of bidding for GA allocation. In addition, this portal must also provide a single redressal platform to address the different challenges, including land allocation, RoU permission etc., to help expedite the expansion of the CGD network.

CREATION OF STRATEGIC NATURAL GAS STORAGES

To increase gas share in the primary energy mix, the CGD network is expanding exponentially, leading to a significant shift in using natural gas as a cooking fuel. To address any adverse supply chain disruptions, India needs to consider the establishment of storage facilities equivalent to a certain number of days of national consumption, which may include development of UGS facilities using depleted oil & gas fields, salt caverns and aquifers of capacity, over time, equivalent to store up to two months of natural gas consumption. It is worth noting that countries in Europe and America have strategic gas reserves of around four months. These depleted storages can also be offered on a competitive basis to interested gas marketers or overseas gas-producing companies as applicable. For long-term sustenance, the model will need to be financially viable, which requires a supportive policy, tax incentives, commercial framework and financing.

PROMOTING LNG-BASED TRANSPORT IN THE LCV & HCV SEGMENT

Liquefied Natural Gas (LNG) for Light Commercial Vehicles (LCV) and Heavy Commercial Vehicles (HCV) is the most efficient way of reducing carbon and particulate emissions, which will result in cleaner air of 'Good' Air Quality Index (AQI) across the country. Considering its lower emissions and higher calorific values than diesel, LNG is a promising alternative fuel. It will contribute during the transition journey and be vital to achieving the net zero target. Although MoP&NG has provided targets to set up LNG stations across major highways, including the Golden Quadrilateral, the program will be a real success if conversion of existing diesel vehicles to LNG based is duly incentivized by the Government of India so that investments made towards creating this ecosystem results in fair returns to all stakeholders. Coordinated actions among all key stakeholders, viz. Government, Gas Industry and automobile manufacturers will go a long way to ensure the requisite financial support, technology availability, faster fleet conversion etc. As an enabler, a suitable policy must be notified in this regard.

INCLUDE NATURAL GAS UNDER GST

The alternative fuels to natural gas are already under the purview of GST, enabling stakeholders to avail of GST input tax credits. Currently, credit for taxes paid on the gas value chain is unavailable, which leads to complex compliances and higher costs due to stranded tax credit. This acts as a deterrent for industrial consumers to switch to natural gas. Therefore, it is necessary to include natural gas under the purview of GST to promote the transition towards a cleaner gas-based economy. At the same time, high volatility in natural gas prices necessitates that taxes should be levied such that the landing price at the customer end is cheaper than alternate fuels at all points of time. Therefore, taxes may be considered on a specific value-based rather than on an ad-valorem basis and appropriately modulated to ensure that gas consumption remains competitive.

ENSURING ENHANCED DOMESTIC GAS AVAILABILITY

CBG potential needs to be realized to its fullest by addressing the challenges in this sector. Going by current business ecosystem, it is worthwhile to note that only CBG plants based on press mud can operate at name plate capacity. In contrast, agriculture residue-based & Municipal Solid Waste (MSW) plants are yet to achieve this feat. Further, MSW-based CBG plants are most difficult to secure industry investment considering challenges of non-quantification of raw material, feedstock availability & quality, land parcel allocation etc.

Further, there is a need to encourage CGD entities to set up CBG plants in respective GAs under SATAT, aligned to the grid, to ease evacuation of CBG through injection into the pipeline. This will boost propagation of the Government of India's SATAT scheme and help achieve net zero target.

Therefore, policy support is required, including financial incentives to provide the impetus for setting up MSW-based CBG plants across the country. For CBG to take off in a big way, it is necessary to ensure the availability of finance, support the creation of a supply chain and ensure the preferred availability of bio-material. Moreover, India has large coal reserves; coal gasification can be an excellent potential source for transitioning away from the direct usage of coal. As coal gasification is a capital-intensive process, it is necessary to provide financial support for coal gasification to acquire scale. Further, coal gasification should be based on lower energy intensive technology suited to Indian coal or use green energy. So, the country must continue to invest in Research & Development.

GAS MARKET & INDEX

Given the declared objective of the Government to increase the share of gas in the energy mix, it is critical that the country has an efficient gas market. The country also needs to strengthen the Gas Exchange in this regard for a faster transition towards natural gas from conventional hydrocarbons. It may also be noted that with the significant increase in consumption, India can leverage its buying position. This provides an opportunity for the country to develop its own index. Generally, indices are developed by net-exporting countries such as Henry hub, USA; Brent crude oil index (adopted by Middle East countries) and others. India, with a long shoreline and massive investments underway in gas-related infrastructure like LNG terminals, CGD and gas pipeline network, is already slated to become a major global demand center for incremental energy in general. For interesting energy-related business models to develop and flourish in the gas space, India should try to develop its own reference index in the lines of Japan-Korea Marker (JKM), which references the consuming nations. This can also serve as a regional index to negotiate the terms of LNG contracts which may eventually help mitigate the volatility of LNG prices.

Chapter 11

DIESEL – FUTURE POSSIBILITIES & BLENDING

In this section

INTRODUCTION – FUTURE OF DIESEL

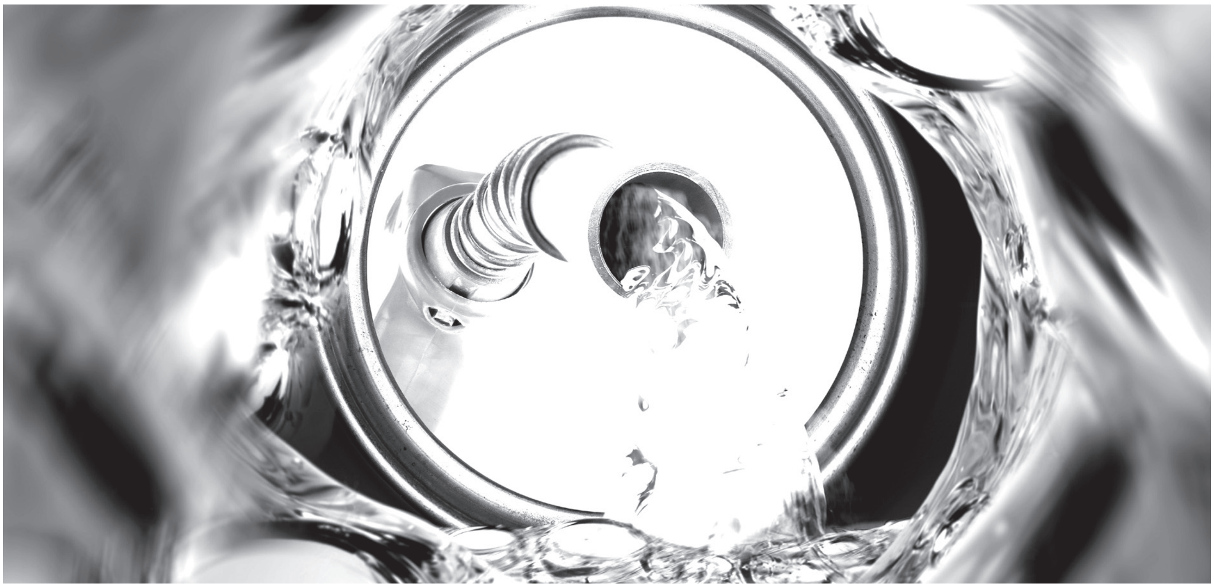
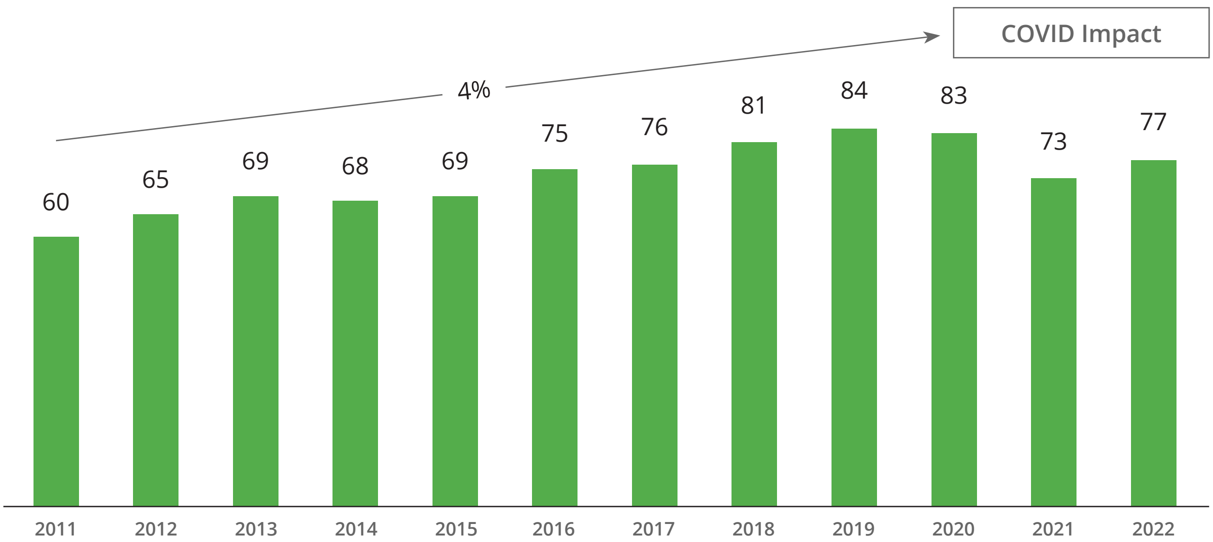


Photo Credit: Adobe Stock

Diesel currently accounts for about 40% of India's petroleum products[1] consumption. Diesel consumption increased from 60.01 MMT in 2011 to 83.53 MMT in 2019. Consumption dropped to 82.60 and 72.71 MMT in 2020 and 2021 on account of COVID impact and reduced economic activity (Exhibit-11.1). Consumption improved to 76.69 MMT in 2022 and it is expected to reach 79.3 million in the fiscal year 2023 (still projected to be lower than pre COVID levels).

Exhibit-11.1: Diesel Consumption in India (in Million Metric Tonne)



Source: Petroleum Planning & Analysis Cell

Exhibit-11.2 shows the end-use sales of High-Speed Diesel (HSD) across different segments and the change in the consumption mix from 2013 to 2021. The transport sector contributed to about 80% of the total diesel demand in 2021, up from 70% in 2013. The most significant shift occurred in the commercial trucks segment, where the demand doubled from 28.25% (19.5 MMT) to 55.40% (40.3

[1] Petroleum Planning & Analysis Cell, MoP&NG, Government of India

MMT). However, the share of diesel demand from other transport segments including private taxis, three-wheelers, and buses has reduced over the last eight years. The demand from commercial taxis dropped from 8.94% (6.2 MMT) to 2.90% (2.1 MMT) and private vehicle diesel demand dropped marginally from 13.15% (9.1 MMT) to 12.4% (9 MMT). Consumption from the 3-wheeler segment dropped from 6.39% (4.4 MMT) to 1.20% (0.9 MMT). Demand from buses also dropped by a third, from 9.55% (6.6 MMT) to 5.90% (4.3 MMT).

Demand contribution from the non-transport sector also decreased from 30% in 2013 (20.7 MMT) to 19.3% in 2021 (14 MMT), witnessing reductions both in share as well as in volume even if overall offtake of diesel in the country increased. Similarly, diesel usage declined in the agriculture sector from 13% (9 MMT) to 4.80% (3.5 MMT) as the industry moved towards greener alternatives like solar energy. The diesel demand for power generation and mobile towers also reduced from 4.06% (2.8 MMT) and 1.54% (1.1 MMT) to 1.60% (1.2 MMT) and 0.30% (0.2 MMT), respectively. However, the use of diesel for industrial applications has increased from 4.96% (3.4 MMT) to 6.30% (4.6 MMT) driven by growth in the underlying demand sectors.

Exhibit-11.2: Diesel consumption across various sectors

Source: Petroleum Planning & Analysis Cell

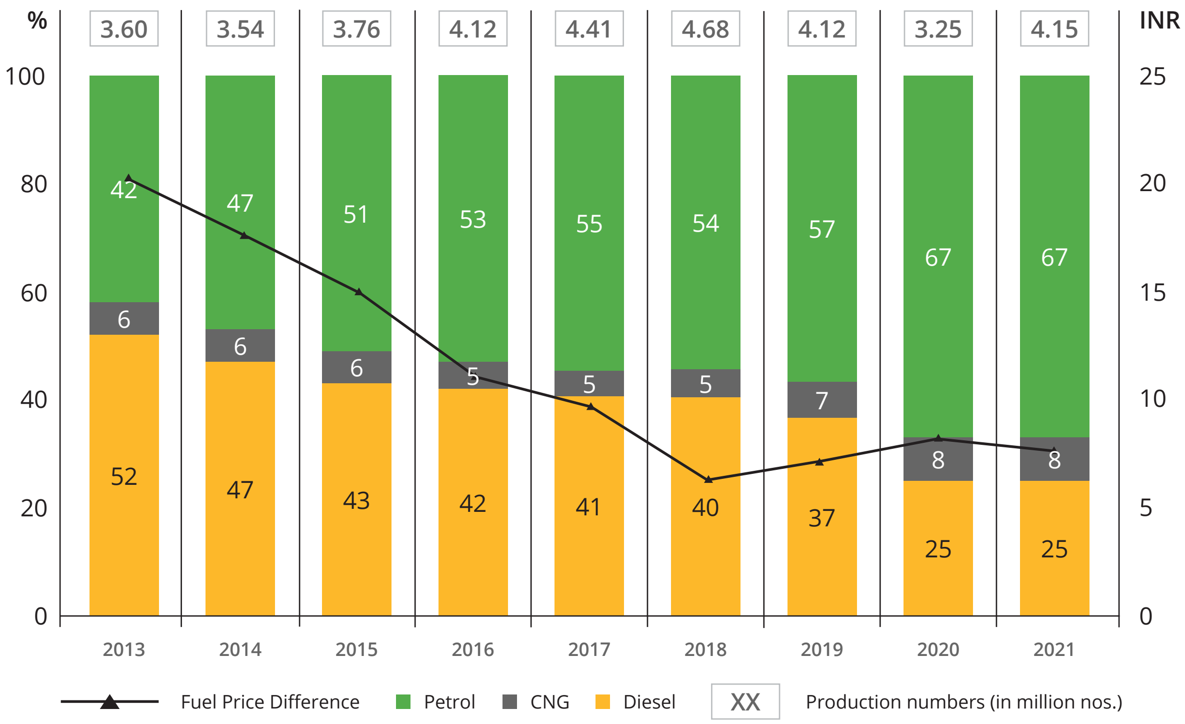
DIESEL DEMAND FROM THE TRANSPORT SECTOR

DEMAND FROM PASSENGER VEHICLE SEGMENT

Passenger vehicles contribute to 16.5% of diesel demand today, considerably lower than 28.5% in 2013. While overall diesel consumption increased from 69 MMT in 2013 to 73 MMT in 2021, the demand from the passenger vehicles segment dropped from 19.67 MMT to 12 MMT over the same period. The lower cost of diesel in comparison to petrol had historically driven demand for diesel engine powered passenger cars. While the initial purchase cost of diesel engine vehicles is higher than petrol engine vehicles, the lower cost of diesel fuel translated to a lower total cost of ownership for consumers.

The price difference between petrol and diesel fuels has come down significantly from 26 rupees in 2012 to just 8 rupees in 2021 (Exhibit-11.3). The demand for diesel engine passenger vehicles has also seen a steady decline over this period. From 52% share in the passenger vehicle segment in 2013, diesel vehicles in the mix reduced to 25% in 2021. The consumption of diesel from the commercial taxi segment, which is more price-sensitive to fuel prices, has seen a steep decline from 8.94% (6.2 MMT) in 2013 to 2.90% (2.1 MMT) in 2021.

Exhibit-11.3: Production of passenger vehicles by fuel type (in million nos.)



Source: S&P Global Mobility

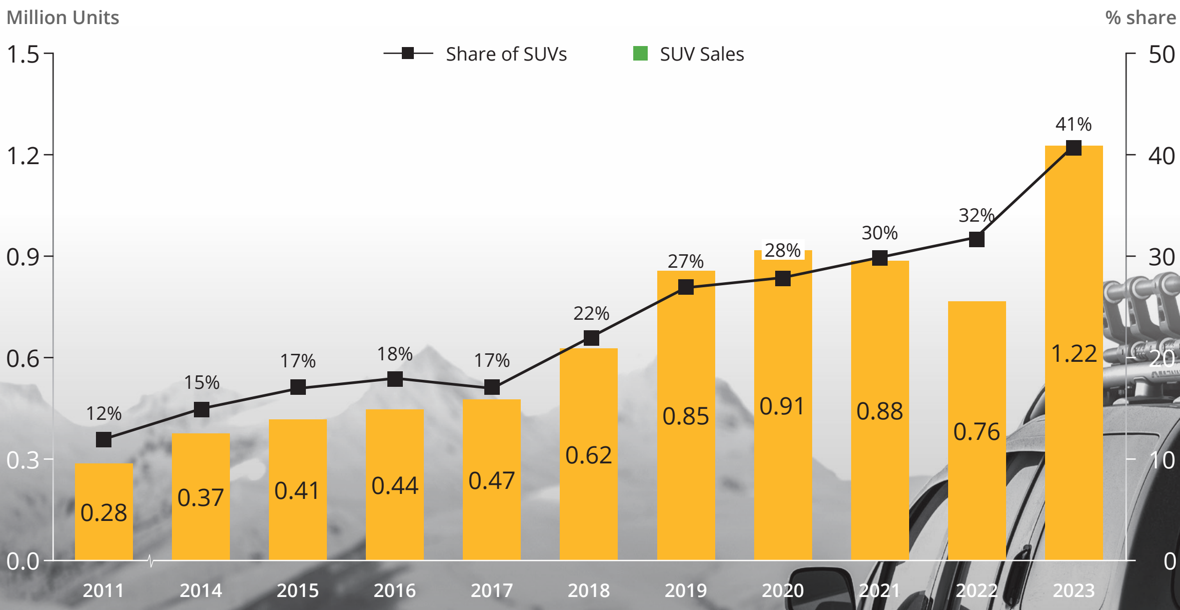
Further, the cost of production of diesel engine vehicles has increased with the implementation of BS-VI emission norms. While petrol engine vehicles saw an increase in cost of INR 10,000 - 30,000, diesel engine cars have increased by INR 40,000 – 120,000.

The BS-VI Stage-II emission norms, planned to be implemented in 2023, are expected to further increase the cost of production. In response to these changes, several automotive OEMs have already announced plans to phase out diesel passenger vehicles from their portfolio.

Maruti Suzuki has already phased out diesel vehicles from its portfolio in 2020. Tata, Mahindra and Honda have also discontinued producing 1.2-Liter diesel engines. Diesel variants are available only for engine capacity of 1.5-Liter or higher. Hyundai introduced 1.2-Liter BS-VI complaint diesel variants in Grand i10 NIOS and Aura models in 2020 but has discontinued the production of 1.2-liter diesel vehicles from 2022.

The impact on diesel demand from the drop in sales of diesel engine cars has been partially offset by the increase in demand for SUVs in the market, which have a larger fill size compared to hatchbacks and sedans. The share of SUV production in India increased from 12% (0.28 Mn) in 2011 to 41% (1.22 Mn) in the calendar year 2021 (Exhibit 4). The share of diesel-engine variants is about 35-40% in compact SUVs, while it is about 55-60% in mid-size SUVs. The average fuel fill size of SUVs is 27 Litres, compared to 17 Litres for other passenger vehicles[2]. The dominance of SUVs is expected to continue, and diesel demand is expected to remain strong in this segment.

Exhibit-11.4: Sale of SUVs in India



Source: S&P Global Mobility

Photo Credit: Adobe Stock

[2] PPAC study on all India sector demand for petrol and diesel (2021)

Diesel is being displaced in the 3-wheeler segment also. The sales of diesel 3-wheelers reduced from 290,298 in 2020 to 63,272 in 2022. Diesel demand from this segment reduced from about 4.4 MMT (2013, 40% share in sales) to 0.9 MMT (2021, 16% share in sales), driven by the increase in sales of CNG and electric 3-wheelers. In FY2022, electric and CNG vehicles contributed to 46% and 27% of the total 3-wheeler sales, respectively (Exhibit-11.5).

The share of electric 3-wheelers increased from 15,502 in 2016 to 177,872 in 2022.

Diesel demand from the passenger vehicle segment is expected to continue its decline, driven by the higher cost of ownership of diesel vehicles and the declining price gap between diesel and petrol. Further, demand for EVs has been on the rise in India.

Demand drivers for EV sales

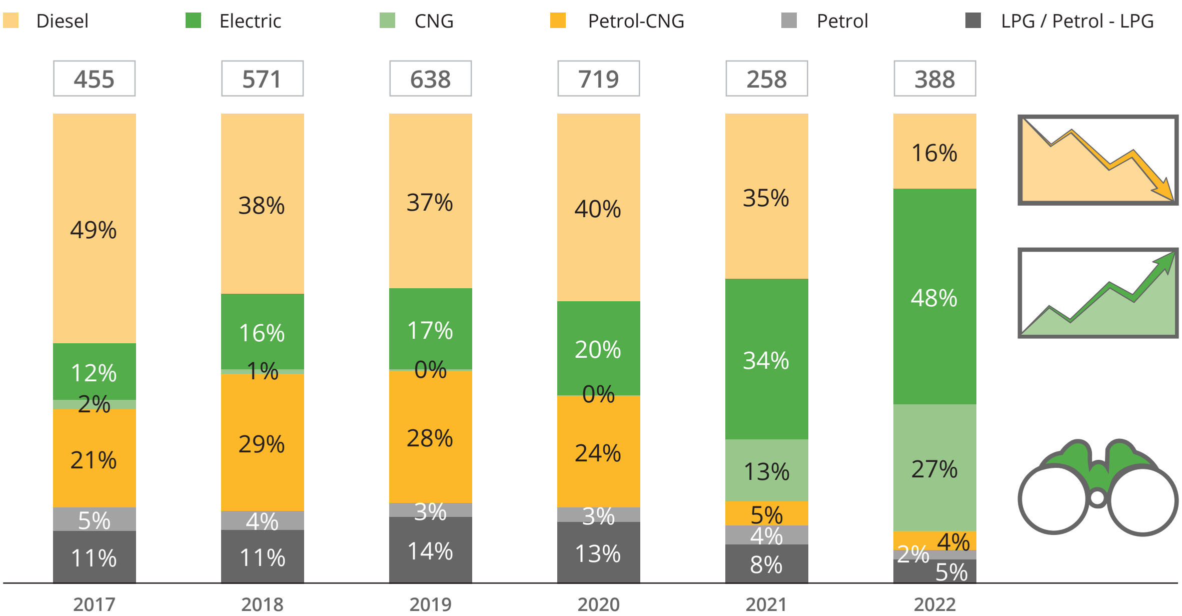
Increasing public awareness about pollution and climate change has been driving a shift in consumer preferences toward cleaner options of travel including EVs.

While the upfront purchase costs for EVs are significantly higher, the operating cost of EVs is lower than petrol and diesel vehicles.

EVs also have lower maintenance costs as they have fewer moving parts than traditional combustion engine powered vehicles.

Government of India is providing various incentives to boost EV sales including direct discounts on the cost of EVs, road tax exemption, low interest rates on EV car loans, and income tax benefits.

Exhibit-11.5: Sale of 3-wheelers in India (in '000 nos.)*



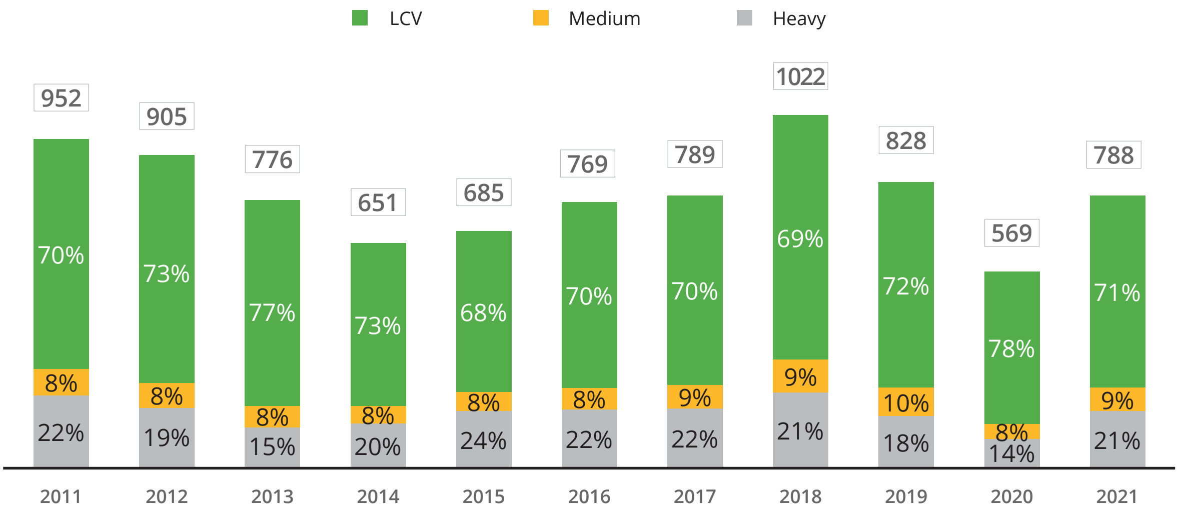
** Data does not include sales figures from four states, i.e. AP, MP, TS & LD*

Source: VAHAN database, Ministry of Road Transport & Highways

DEMAND FROM TRUCKS: HCV / LCV

The diesel consumption from the commercial vehicles segment has increased from 28% (19.5 MMT) in 2013 to about 55% (40.3 MMT) in 2021. The freight movement by road increased from 1.52 trillion tonnes km in 2013 to 2.67 trillion tonnes km in 2019[3]. Around 65% of India's overall freight transportation is carried out by road, with LCVs accounting for ~70% of the market sales (Exhibit-11.6). With the agriculture and manufacturing sectors dependent heavily on road logistics, diesel demand from this sector is expected to continue its growth.

Exhibit-11.6: Sale of commercial trucks (in '000 nos.)



Source: S&P Global Mobility

In 2021, the government of India launched Voluntary Vehicle Scrappage Policy to phase out old and unfit vehicles. Under the policy, commercial vehicles more than 15 years old and passenger vehicles more than 20 years old will have to be mandatorily scrapped if they do not pass emission and fitness tests. Incentives that were provided under this scheme to scrap old vehicles and purchase new vehicles include zero registration charges for new vehicles, a rebate on road tax, and a discount of up to 5% on new vehicles from manufacturers. This policy is expected to reduce pollution and increase demand for new vehicles. As per Ministry of Road Transport and Highways, it is estimated that more than 17 lakh commercial vehicles (both buses and trucks) in India are older than 15 years and unfit for service. While replacement of the older vehicles will drive demand for vehicles, newer vehicles are more fuel efficient, and the transition is therefore expected to result in lower fuel consumption. Similar to the passenger vehicle segment, attempts to transition from internal combustion engines have been underway in the commercial vehicle segment also. Electric vehicles and hydrogen fuel cell-powered vehicles are being explored as alternate power drives to internal combustion engines in heavy vehicles. OEMs including Tesla are undertaking extensive research to develop electric trucks with a range of 800-1000 Km, which if successful, has the potential to disrupt supply chains worldwide and reduce logistic costs and emissions.

[3] *Ministry of Road Transport and Highways, Government of India*

The success achieved in transitioning the heavy vehicle segment, especially in long haul transport, has been limited thus far.

1. Energy density of lithium-ion batteries and resultant weight of batteries are not conducive for heavy vehicles in long haul applications
2. The current charging times are high, which significantly reduces the utilization of the vehicles
3. The charging infrastructure is in nascency in most markets & requires significant investment to complete build-out of network

OEMs like Toyota are also exploring hydrogen fuel cell technology as an alternative. The Government of India is investing in research and development of green hydrogen and intends to produce 75% of the country's hydrogen from renewable energy sources by 2050. Adani group and Total Energies of France have recently formed a partnership to develop the world's largest green hydrogen ecosystem. The Company plans to invest US$ 50 Bn over the next ten years to develop green hydrogen production capacity of 1 Mn tons per annum. Reliance Industries also plans to invest USD$ 75 Bn in renewable energy over the next decade. Indian energy sector PSUs also have their own hydrogen plans, which, if successful, could help find options for hydrogen as a transport fuel. Hydrogen fuel cells have ten times higher energy density than lithium-ion batteries. Hydrogen fuel cell vehicles can also be refueled quickly in comparison to EVs minimizing the impact on the utilization of the trucks. But some technical and commercial challenges are yet to be solved for the adoption of green hydrogen as a transport fuel. Green hydrogen is more expensive (in comparison to gray hydrogen as well as other transport fuels), and costs under current conditions will be in excess of US$4-5 per kg. The transportation of hydrogen is complex, capex intensive and needs to address underlying safety considerations. In summary, hydrogen fuel cell technology, while promising, is still nascent, and commercial readiness is yet to be established.

Fuel innovations in traditional combustion engines of heavy vehicle segment are being explored. Alternate fuels that can be used in internal combustion engines include CNG and LNG. However, CNG and LNG cannot be directly used in existing vehicles without modifications.

LNG-powered Trucks

Liquefied Natural Gas (LNG) as a road transport fuel is seeing a surge in demand globally over the past few years, and segment LNG demand reached 11.7 MMT in 2020[4]. Rapid expansion of LNG consumption has been driven by strong government efforts in Asia and Europe to move away from diesel vehicles. China has become the largest market for LNG in road transport since the introduction of LNG as an alternate fuel for heavy-duty vehicles. China's total fleet of LNG-powered trucks crossed 300,000 in 2019.

LNG is used for long-range medium and heavy-duty vehicles because of its higher energy density when compared to compressed natural gas. The energy density of LNG is 22 MJ/L (~60% of diesel, 2.4x of CNG). The demand for LNG vehicles is strongly dictated by the cost competitiveness of LNG over diesel. LNG cannot be directly used in current internal combustion engines, and the cost of conversion is about US$10,000 per vehicle. The payback period on the conversion cost is dictated by the price difference between diesel and LNG. Currently, LNG-powered trucks are not available in India. While TATA Motors unveiled an LNG truck at the Auto Expo in 2014, no vehicles have been released in the market yet. The focus of Indian Auto OEMs has been on CNG-powered trucks, which are seeing an increase in demand.

[4] *World LNG Report, International Gas Union*

Adoption of LNG in commercial vehicle segment faces some hurdles:

1. Countries are ultimately looking to move towards zero-emission vehicles. As such, LNG is seen as a technology bridge in the long-term vision of a fully emission-free transportation industry.

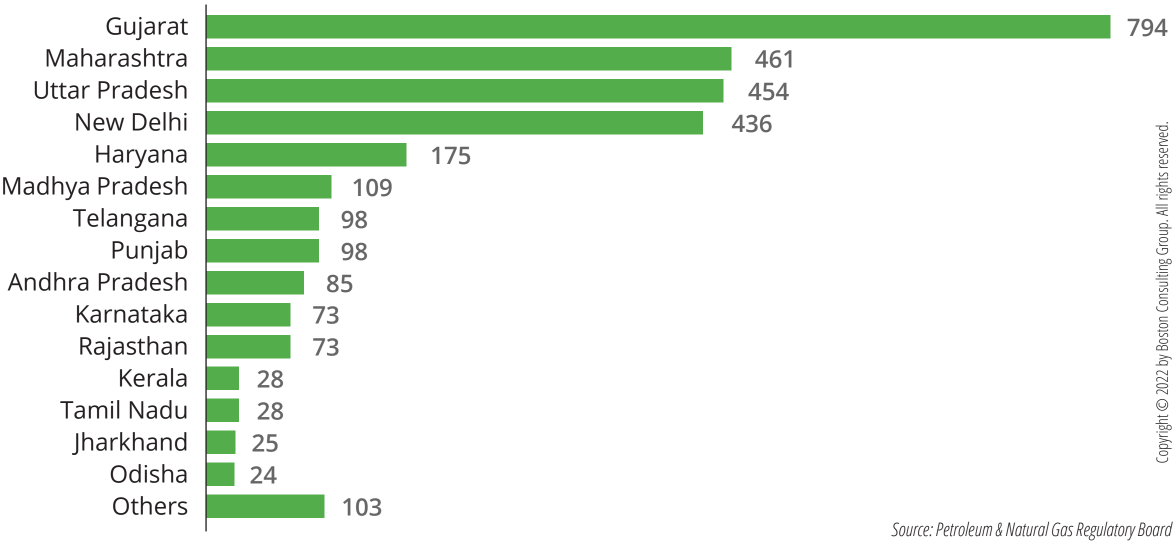
2. Tank-to-wheel emissions of LNG are 22% lower than diesel. But, concerns remain around the overall well-to-wheel GHG emissions from use of LNG including methane emissions during upstream production of shale gas[5].

3. The refuelling infrastructure for LNG and cost-effective conversion technologies of diesel to LNG trucks must be developed to boost the demand for LNG trucks. This will require capital investments from private and government sector.

CNG-powered Trucks

The demand for CNG-powered commercial vehicles in light and small segments has rapidly increased over last two years. According to Society of Indian Automobile Manufacturers (SIAM), the sales share of CNG trucks reached 10% in FY 2021-22. TATA Motors has seen an increase in share of CNG vehicles in light and small commercial segments from 16% & 5% in FY 2020-21 to 44% & 33% in FY 2021-22, respectively. In its overall commercial portfolio, CNG accounted for over 16% of sales in FY2021-22, against 3.4% in FY2020-21. The increase in demand has been driven by the rise in diesel prices, the government's push for greener vehicles, and the improving CNG infrastructure in the country. However, cost of natural gas has also increased by about 25% in 2022, driven by market changes in the global gas market and is a deterrent for larger adoption. CNG is suitable for light commercial vehicles for shorter ranges (up to 400 km/day), given its low energy density. The energy density of CNG is 9 MJ/L which is about 25% of diesel. 98% of CNG sales to trucks is concentrated in five states – Delhi, Maharashtra, UP, Gujarat, & Haryana. CNG infrastructure is well developed in these states compared to rest of the country, and they account for 75% of the total refueling stations (Exhibit-11.7). Refueling infrastructure should be developed nationwide to boost CNG vehicles market. The diesel demand from this sized vehicle segment is expected to drop in the future with the increase in penetration of CNG in light and small commercial vehicles.

Exhibit-11.7: CNG stations across India as of May 2021



Source: Petroleum & Natural Gas Regulatory Board

[5] *LNG Trucks: A Bridge to Nowhere, International Council on Clean Transportation, 2020*

DEMAND FROM BUSES

The diesel demand from buses decreased from 9.55% (6.6 MMT) in 2013 to 5.90% (4.3 MMT) in 2021. As of 2019, there are 1.9 Mn buses in the country. However, it is estimated that India needs about 3 million buses to meet its demand for public transport. There is a large gap between the supply and need for both public and private buses. Multiple Indian cities are undertaking improvements in the road infrastructure and increasing the number of buses in operation to bridge this gap. This is expected to drive an increase in the sales volume of buses.

In 2021, the Indian government allotted INR 18,000 Crores to acquire, operate and maintain 20,000 buses for public transportation through public-private partnership models. This will further boost the demand for diesel in the coming years. However, the adoption of electric buses has also increased for inter-city commutes. This segment is expected to thrive as the government is trying to push EVs through policies like FAME-II. Electric buses continue to face some hurdles, including lower utilization, low ranges, and inadequate charging infrastructure. Electric buses currently available in the market offer a range of 150 - 200 km and require a charge time of 3-4 hours using DC fast chargers. The charging time is higher if AC charges are used. Given the current limitations of electric buses, the impact on diesel demand is expected to be marginal in the near term. However, in the mid to long term, electric buses are expected to gain a larger share in the intra-city passenger transport segment.

DEMAND FROM THE RAIL SEGMENT

Photo Credit: Adobe Stock

The demand share of diesel from the railway sector dropped from 3.24% in 2013 to 2.1% in 2021. The diesel consumption from railways decreased from 3.06 Bn Litres in FY 2018-19 to 1.63 Bn Litres in FY 2020-21. The demand will further reduce as the government is targeting 100% electrification in rail. 80% (52,247 km) of the entire rail network was electrified as of March 2022, up from 30% in 2010. It is expected to reach 100% electrification in the next 2-3 years. The government is also trying to downsize the Indian Railways' fleet of diesel locomotives. As of December 2021, Indian Railways operates about 13,500 trains, of which diesel locomotives haul only 37% (5,000 trains) currently. Over the next few years, diesel locomotive usage is expected to become marginal, and diesel consumption from this sector will become negligible.

DIESEL DEMAND FROM THE NON-TRANSPORT SECTOR

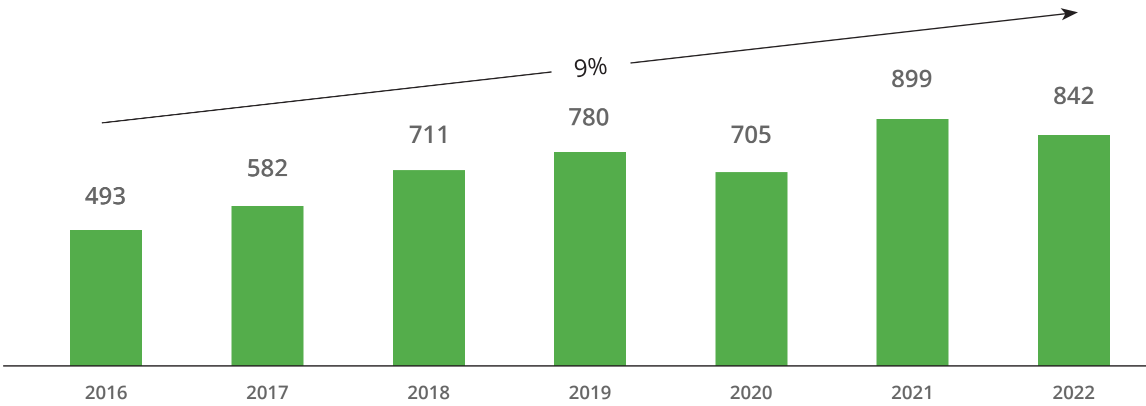
Diesel demand from the non-transport sector has reduced from 30% (20.7 MMT) to 19.7% (14 MMT) over the past eight years. The demand is expected to go down further with the increased usage and availability of alternative energy sources. The most significant transition is taking place in the agriculture sector, where farmers are moving to solar energy. Diesel usage in agriculture has reduced significantly from 13% to 4.8%. The diesel demand for power generation also declined from 4.06% (2.8 MMT) to 1.60% (1.2 MMT).

AGRICULTURE

The use of diesel in agriculture has come down from 8.98 MMT in 2012-13 to 3.5 MMT in 2020-21. The demand in this sector comes primarily from consumption for tractors, water pumps, and other agricultural equipment.

Tractor sales have increased from 4,93,400 in FY 2016 to 7,80,032 in FY2019. The sales dropped to 7,05,011 in FY 2020, but the sales picked up in FY 2021 and reached an all-time high of 8,99,407 (Exhibit-11.8).

Exhibit-11.8: Tractor Sales in India ('000 nos.)



Source: Tractor Manufacturers Association

The government is targeting to replace diesel with renewable sources in agricultural equipment and machinery by the end of 2024. The initiative is part of India's commitment to achieve 40% of the electricity capacity from non-fossil energy sources by 2030 and become a net-zero emitter by the year 2070.

Government of India launched PM Kusum Scheme in 2019 to increase the use of renewable energy in the agricultural sector. The scheme has three components.

1 Installing 10 GW of grid-connected renewable energy power plants.

2 Installing 1.75 Mn stand-alone solar pumps to replace the existing diesel pumps in off-grid areas

3 Converting 1 Mn existing grid-connected agricultural pumps to solar.

Government will financially support farmers by subsidizing 60% of the project costs and providing 30% in the form of a loan. Sales of solar pumps have increased from 11,626 to 246,074, with a CAGR of 66% between 2014 and 2020. There is also a push for petrol and flex engine-based agriculture equipment instead of diesel, as these can be run on ethanol.

Thus, while the demand from tractors is expected to remain strong, overall demand for diesel from agricultural sector is expected to decline.

MOBILE TOWERS

Photo Credit: Adobe Stock

The demand for diesel from mobile towers reduced from 1.54% (1.1 MMT) in 2013 to 0.30% (0.2 MMT) in 2021. The improved connectivity of the country's grid infrastructure, access to solar-powered energy sources, and a strong government push have reduced the industry's dependence on diesel generators. Out of more than 520,000 mobile towers installed across the country, only 4% are off grid with no access to electricity, down from 36% in 2014[6].

The Government of India is also incentivizing companies to move away from diesel generators through net metering policies, group captive models, and reduction of subsidies on diesel. While diesel-based power generators are still used for backup, due to their high operating costs, companies are switching to batteries for backup in case of power outages, impacting diesel usage. Demand for diesel from telecom sector is expected decline and become negligible.

OTHER INDUSTRIAL APPLICATIONS

Diesel is also heavily used in the construction and mining industries for the operation of heavy machinery like cranes and crushers. Demand for diesel from this sector is ~6.3% (4.6 MMT, 2021), up from 4.96% (3.4 MMT) in 2013. Road infrastructure in the country has seen rapid growth over the past few years, with the length of National Highways constructed increasing from 4,510 km in 2015 to 16,420 km in 2019. The infrastructure sector is expected to continue to grow and has seen a significant inflow of Foreign Direct Investment (FDI). In FY 2020-21, the infrastructure sector accounted for about 13% of the total FDI inflows of USD 81.72 Bn. Currently, there are no viable alternate technologies that can be used to operate the heavy equipment required in construction and mining, and diesel demand from this sector is expected to grow.

[6] *Global System for Mobile Communications Association (GSMA)*

DIESEL ALTERNATIVES & BLENDS

Blends and substitutes to conventional diesel have been explored with the objective of finding cleaner and sustainable alternatives. However, their adoption has been limited thus far globally and in India. The National Policy on Biofuels, 2018 aims to achieve 20% blending in petrol and 5% blending of biodiesel in diesel. The current blending percentages stand at 2% for petrol and less than 0.1% for diesel.

Biodiesel and renewable diesel are the commonly used alternative fuels to diesel and are produced from biomass. Ethanol blending, aided by additives, is also being explored as a cleaner option.

BIO-DIESEL

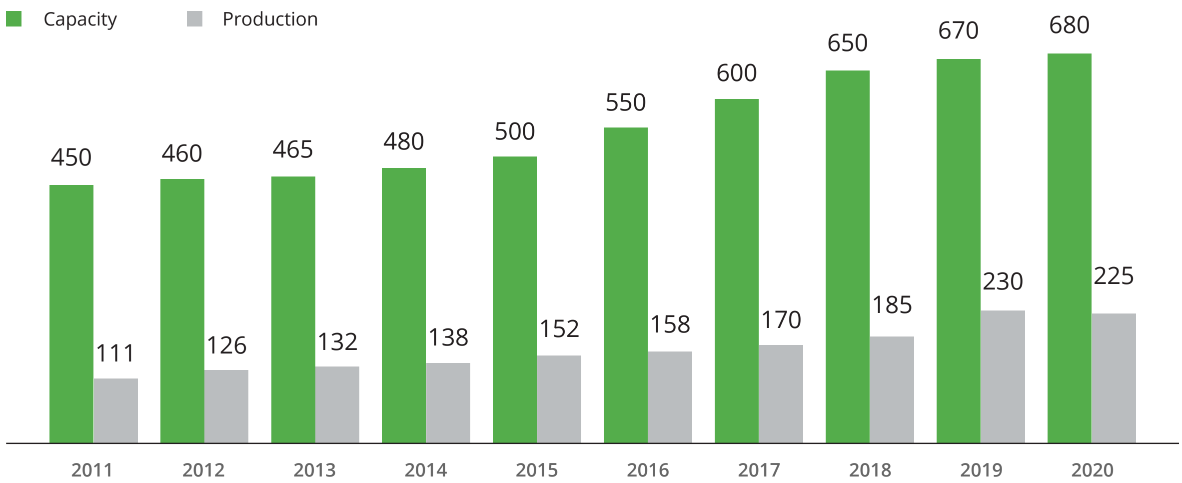
Biodiesel can be produced from different sources, such as used cooking oils (UCO), vegetable oils, and animal fats, through trans-esterification. The physical & chemical properties of biodiesel are similar to diesel, and has several advantages over conventional diesel - Biodiesel is biodegradable, non-toxic, and produces fewer pollutants. However, it can only be used in 2-20% blends with conventional diesel in existing diesel engines since higher blends affect engine durability. Most vehicles in the market today can handle a blend of up to 5%. Biodiesel is also currently more expensive than conventional diesel.

The biodiesel industry in India has not reached scale (Exhibit 11.9), and feedstock availability has been a major constraint in ramping up production. In the 2000s, India invested in developing Jatropha-based biodiesel through the National Biodiesel mission. The government had set a target of 11 Mn hectares of land for Jatropha cultivation. However, only 0.5 Mn hectares of land is currently used for Jatropha cultivation. The gestation period of these crops is also high (3-5 years), which results in a longer payback period. The lack of R&D to improve the yields of Jatropha plantations further disincentivized the large-scale production of these crops.

The current biodiesel production is ~225 Mn Liters against an installed capacity of ~680 Mn Liters, and the existing capacity is underutilized (Exhibit-11.9). Challenges hindering the growth of the biodiesel market include feedstock unavailability and the lack of channels for sourcing raw materials. These issues need to be addressed to drive further growth and private sector investment in biodiesel trans-esterification plants.

A deep dive on Biodiesel is covered in Chapter 4 of the report.

Exhibit-11.9: Production Capacity vs Volume of Biodiesel in India (in million litres)



Source: Global Agricultural Information Network

RENEWABLE DIESEL

Renewable diesel is produced by the hydro-processing of fats, vegetable oils, and waste cooking oils. It is chemically and structurally identical to conventional diesel. Renewable diesel is cleaner and produces 70% lower life-cycle emissions than conventional diesel. Unlike bio-diesel, renewable diesel is 100% interchangeable with conventional diesel and can be used as a direct substitute in vehicles without any modifications. Renewable diesel can be handled by the existing supply chain infrastructure and equipment. Further, renewable diesel can be stored for extended periods without quality deterioration. There are ten production facilities of renewable diesel globally with a cumulative production capacity of about 6.56 Bn Litres as of 2019. Production facilities are concentrated in Europe and USA (Exhibit-11.10).

About 50% of the production is attributable to Neste, the Finnish petroleum refining company. Neste has four operating facilities, with two in Finland, one in Rotterdam and one in Singapore.

Availability of feedstock will dictate scalability of renewable diesel production. Raw material availability must be addressed, and at-scale sourcing channels should be set up to promote growth in production of renewable diesel.

Exhibit-11.10: Global production of renewable diesel

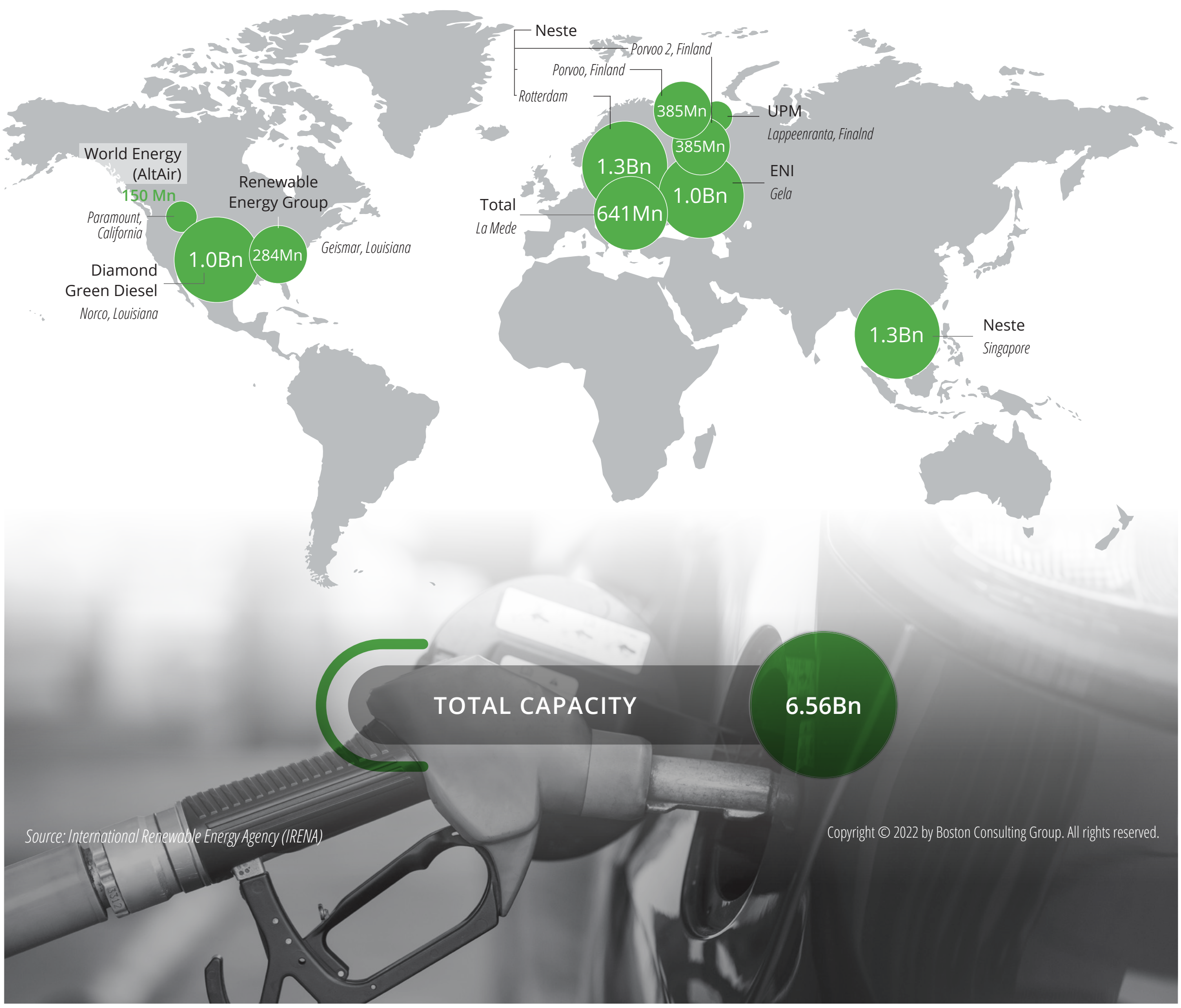


Photo Credit: Adobe Stock

ETHANOL BLENDED DIESEL

Ethanol blending in diesel is constrained (<1%) due to the immiscibility of ethanol in diesel. An additive is needed to blend ethanol with diesel, but available additives in the market are mostly imported. The Automotive Research Association of India (ARAI) is developing an indigenous blending additive that can be manufactured locally. In 2017, ARAI developed a chemical formulation that is commercially viable and manufacturable in the country. ARAI has also developed a process for blending ethanol & diesel.

ARAI has completed performance testing of this blended fuel (90% diesel+7.7% ethanol+2.3% blending additive) on heavy vehicles above 3.5-ton with BS-IV engines. The test results were successful, and no negative impact on engine performance was observed. On ARAI's approval, this blended fuel can be deployed across the country as an immediate solution for vehicles with payload capacity of over 3.5-tons with BS-IV (& below) engine specifications, including trucks, transport buses, and some heavy construction equipment. However, this blended fuel cannot be used for BS-VI engines. ARAI has also collaborated with Praj industries to conduct trials & performance tests on BS-IV and BS-VI vehicles weighing less than 3.5 tons. Apart from trucks, the blended fuel can also be used in diesel generators as engine specifications of these generators are lower or equivalent to BS-IV standards.

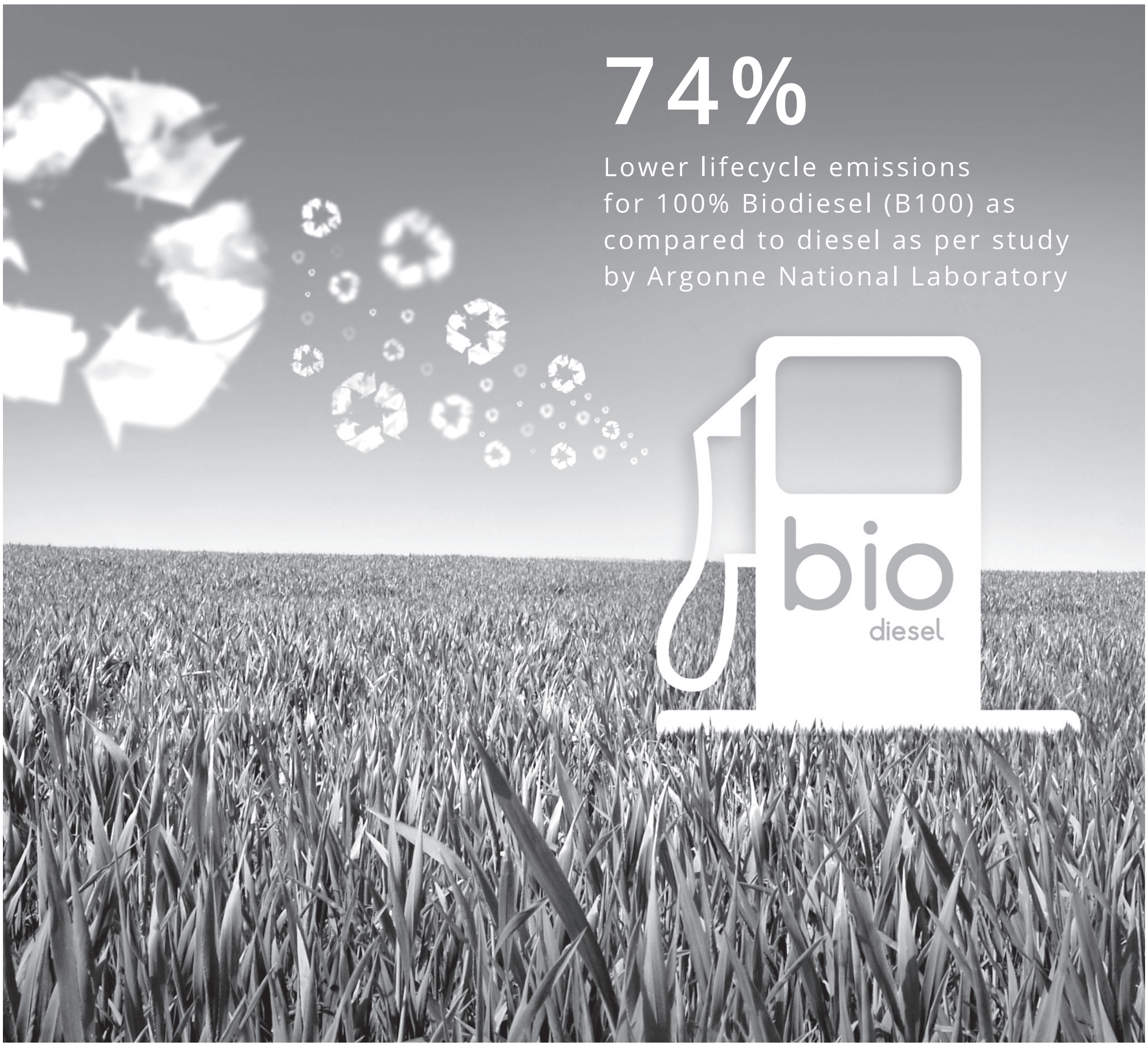


Photo Credit: Adobe Stock

KEY RECOMMENDATIONS

India aspires to continue to grow at a fast pace to become a $20 Trillion economy over the next few decades. The achievement of this kind of growth rate will require the consumption of higher quantities of all forms of energy. Over the near term, as the incremental energy supplied through renewables, energy efficiency/conservation etc., may be low, the offtake of fossil fuel-based energy will continue to rise. However, over the medium and long term, the demand for diesel could be significantly affected due to the following emerging trends:

- **Declining trend in the passenger vehicle segment:** Declining price gap between petrol and diesel, the rise of EVs, the implementation of BS-VI Stage 2 emission norms, and the higher cost of ownership of diesel vehicles have affected the incremental demand for diesel vehicles, which will, in the long run, result in lower offtake.
- **Promote R&D investments in diesel alternatives for heavy vehicles:** Continued R&D investments on use of hydrogen fuel cell powered vehicles as alternate power drives to IC Engines in heavy vehicles will help reduce diesel demand in long term.
- **Push for LNG-powered vehicles:** LNG has the potential to replace both diesel and CNG in heavy-duty vehicles and thereby reduce GHG emissions. Its push in both medium and heavy-duty vehicles, despite cost constraints and higher payback periods, can be a game-changer for the Indian logistics market.
- **Increased investment by government in public transport with a push for the adoption of EVs:** The development of road infrastructure and demand for public transport (buses) will provide a slight uptick in demand for diesel, but increased governmental push for the adoption of EV with FAME-II policy will reduce diesel demand.
- **Higher utilization of renewables in agriculture:** The government is pushing for increased use of renewables in agriculture through the PM Kusum Scheme. This will cause a decline in diesel consumption in the agricultural sector. Although demand for diesel use in tractors is expected to remain strong, overall demand in the agricultural sector is expected to decline due to the increased use of stand-alone solar pumps and the push for flex engine-based agricultural machinery..
- **Establishment of renewable diesel production facilities:** Though scalability concerns exist, India is exploring setting up renewable diesel production facilities due to 70% fewer emissions, 100% interchangeability with conventional diesel and zero modification needs for existing vehicles. In addition, the issues relating to raw material availability necessary for at-scale sourcing channels for renewable diesel production are intended to be addressed over time with the government's push on bio-based energy. Incremental volumes through this route could affect diesel offtake in the long run.
- **Transition mobility to more sustainable modes:** Higher electrification and an increased share of passenger and goods transport by railways will, over time, result in lower diesel offtake. Indian mobility will undergo a paradigm shift under the newly declared National Logistic Policy.
- **Adoption of ethanol blends:** With ARAI in collaboration with Praj developing indigenous additives, blending of Ethanol has specially shown promise and 5% blends can be adopted as it is without any engine modification.

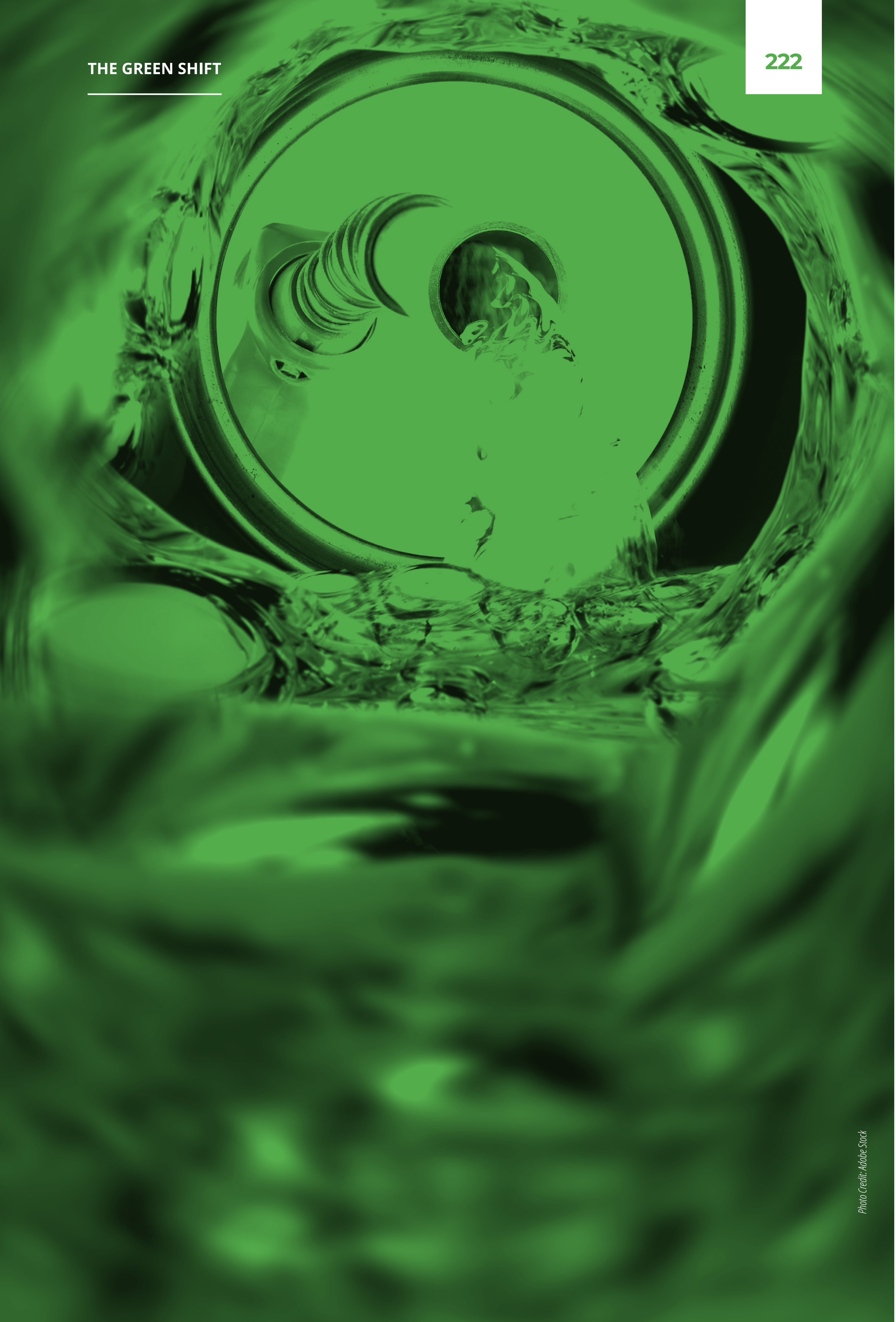


Photo Credit: Adobe Stock

Chapter 12

TECHNOLOGY, INNOVATION AND POLICY SUPPORT

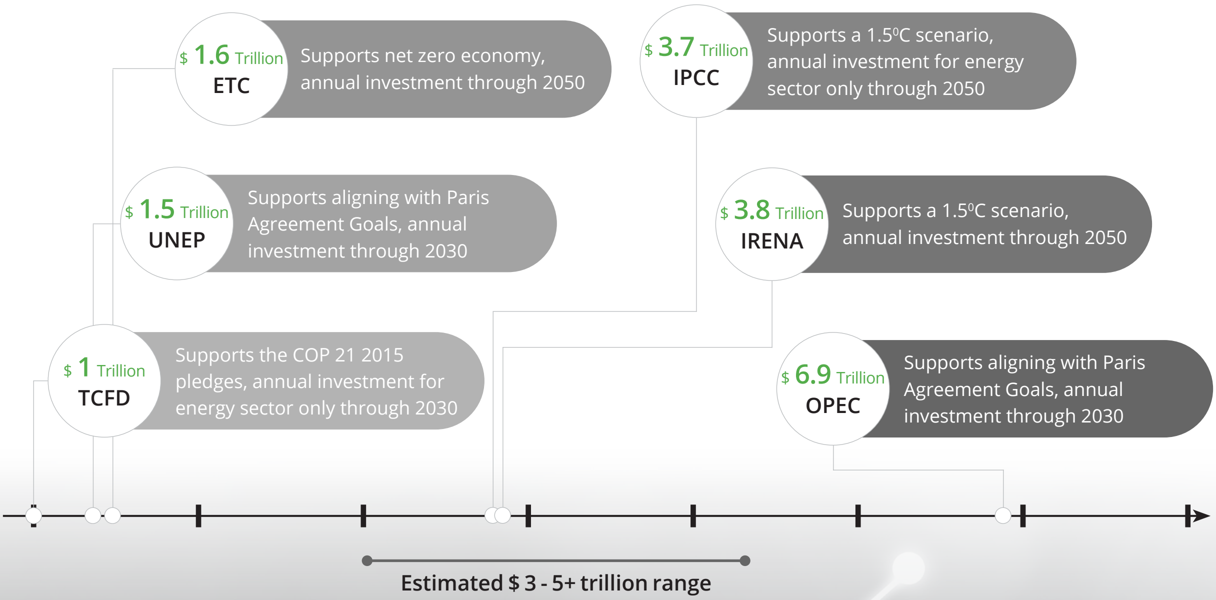
In this section

CLIMATE INNOVATION & INVESTMENT

The sustainability agenda is vital for countries worldwide, and considering the circumstances, it is also a priority to have on top of their minds. Significant strides on pathways towards climate innovation across abatement, capture and removal of emissions are essential to meet the goals of the Paris Agreement. It is estimated that existing technologies can eliminate about 25% of current emissions, and technologies in early adoption can address another 40%. This still leaves approximately 35% of current annual emissions, for which new technologies are needed if we are to achieve net zero as per committed timelines. Climate innovation, therefore, presents a tremendous opportunity – valued at US$3-5 Tn annually (Exhibit-12.1) - for companies to create competitive advantage and long-term value on the path to their net zero goals. Projections by agencies could differ, but it is clear that for the transition journey to reach the intended goal, much depends on yet to be developed technologies. Beyond doubt, transitions will involve substantial investments.

Exhibit-12.1: Modelling for annual investment until 2050 (for next three decades)

An estimated climate investment of $3-5 trillion is required every year to meet the ambitions of Paris Agreement



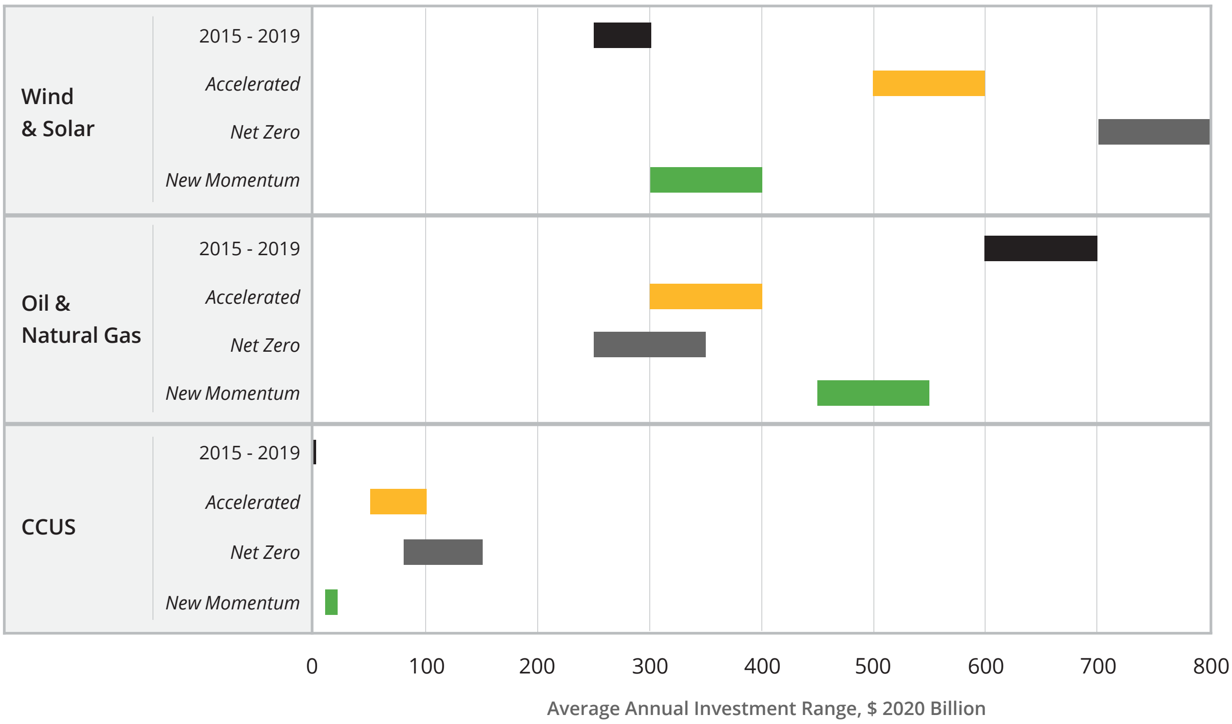
Source: TCFD, ETC, IPCC, IRENA, OECD, UNEP, BCG Analysis

[1] BCG article "Governments That Invest in Climate Innovation Invest in Growth" by Joerg Hildebrandt, Dave Sivaprasad, Marco Duso, Chafic Mourad, Daniel Kiefer, and Bernard Graf

Photo Credit: Adobe Stock

The projections by BP on the segment-wise investments required, as below, also bring out a huge fund requirement for energy transition and the corresponding significant business opportunities that will form the hallmark of the transition journey.

Exhibit-12.2: Investment required towards energy transition



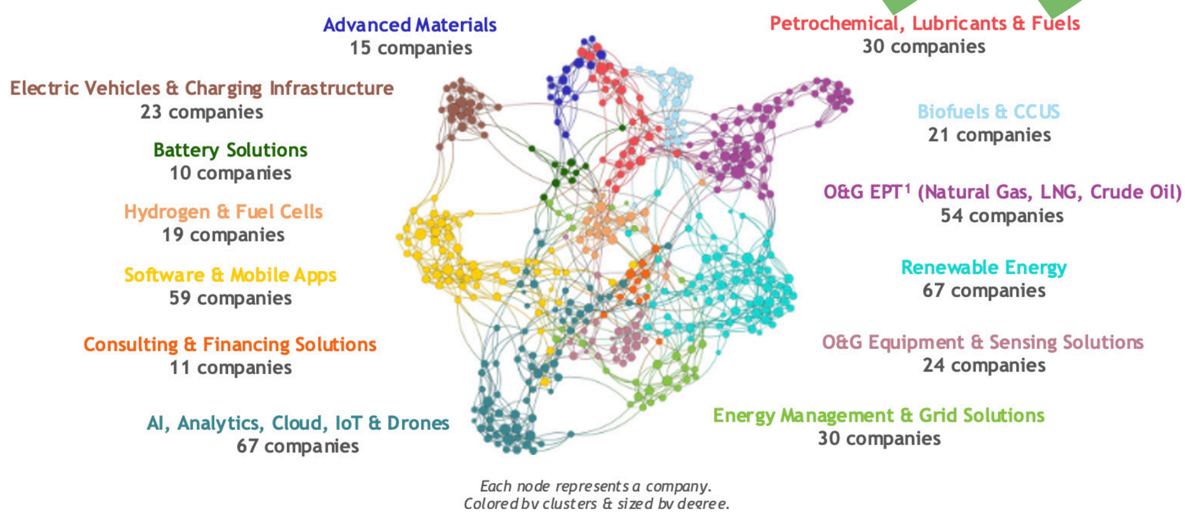
The global oil and gas (O&G) industry is directly or indirectly responsible for close to half of all global GHG emissions. Despite the investment risk perception, O&G companies have also joined the net zero commitments and are investing heavily to attain those objectives. In the past 5 years, 61% of large O&G acquisitions / investments have been in new energy, green tech or digital – where digital has accounted for 30 % of the investments in 5 out of 8 companies (Exhibit-12.2 & 12.3).

India is the 3rd largest consumer of primary energy in the world after the US and China. According to BP Energy Outlook, the energy consumption in India will increase by 129% by 2035 compared to a 31% increase in the global average. Energy is a critical input for socioeconomic development. The energy strategy of a country aims at efficiency, security, affordability, providing environment friendly options and achievement of an optimum mix of primary energy resources. India has committed to reducing its carbon footprint by 30-35% by the year 2030. Achieving this requires investment and innovation across proven and emerging technologies, making India a lucrative market for digital solution providers to drive energy transition strategies and for clean energy technology developers.

Despite the opportunity, climate innovation funding faces challenges as most VC & PE funds are not yet oriented for or leaning towards such investments in a meaningful manner. VCs don't favor the high-risk perception, extended payback cycles and/or lengthy public processes associated with the sector. The lack of understanding of the science and IP further exacerbates the problem. To mitigate these concerns, public funding via co-investment and matching mechanisms helps lower risk perception and mobilize investor interest. The public sector can absorb increased levels of investment risks that are not feasible for the private sector to support leap-frogging technologies and increase overall investor confidence in the domain.

Exhibit-12.3: O&G acquisition / investment in new energy, green tech or digital

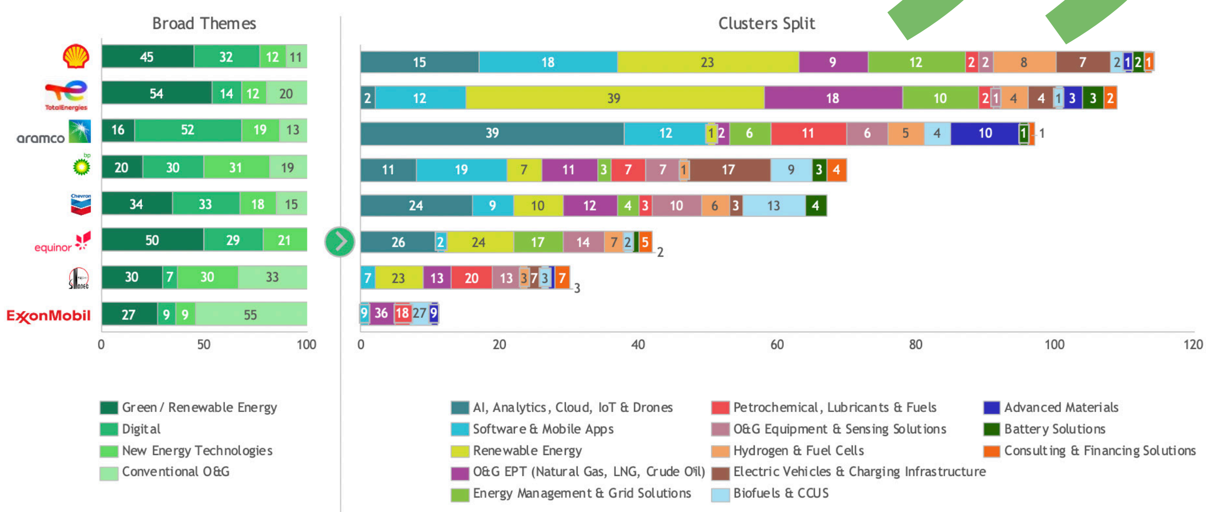
In last 5 years, ~61% of large O&G acquisition / investment have been made in new energy, green tech or digital



Source: Quid, BCG analysis, BCG Center for Growth & Innovation Analytics

Exhibit-12.4: Digital Initiatives by Global O&G Majors

Digital technologies have accounted for more than 30% of the investment in 5 out of following 8 oil & gas majors.



Source: Quid, BCG analysis, BCG Center for Growth & Innovation Analytics

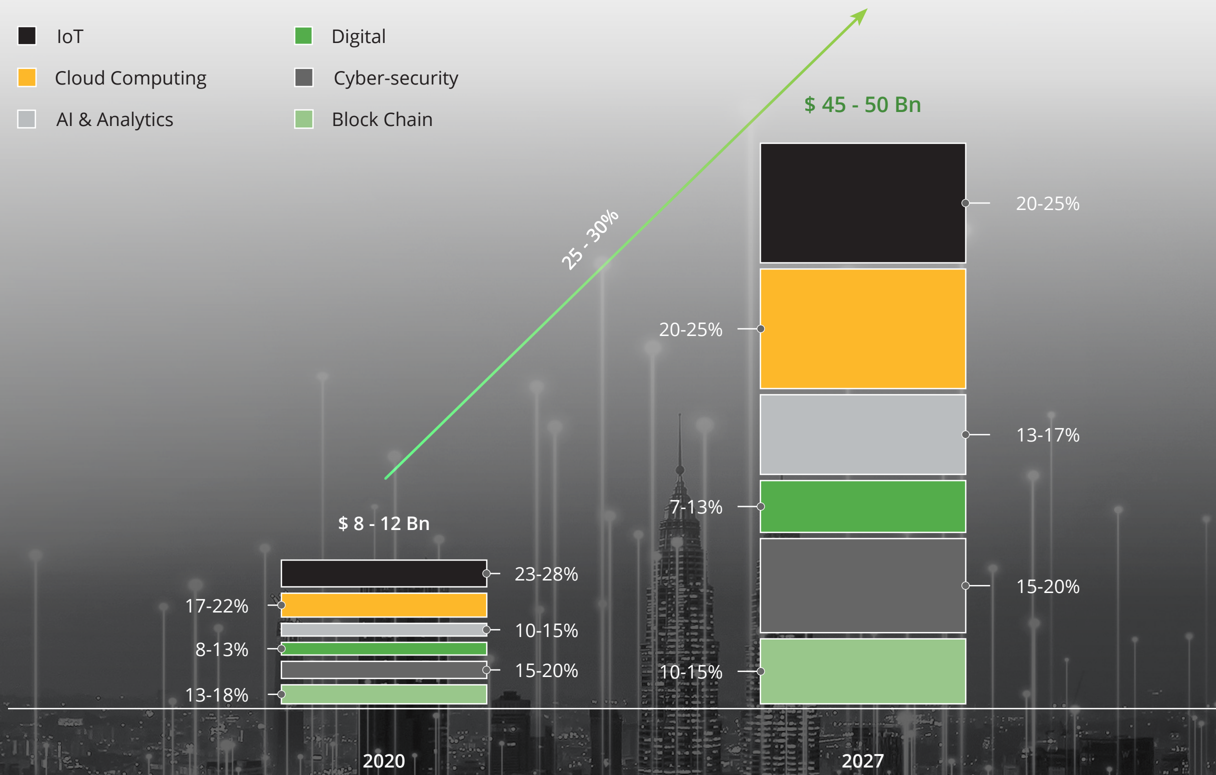
DIGITAL UNLOCK

To realize sustainability as an advantage, technology and data are key levers to magnify both ecological and economic value. Research involving more than 850 companies worldwide has established a clear link between digital capabilities and sustainability, with technology being an enabler to break economic constraints and engineer new solutions.

Increasing adoption of sustainable use cases across IoT (Internet of Things), cloud computing, data platforms & analytics, digital twin and blockchain are driving Green Tech growth. These are expected to grow 25-30% annually for the next 5 years (Exhibit-12.5).

Deployment of these technologies is expected to help ETAC create an integrated ecosystem - combining digital and physical assets – focused on emission monitoring and reduction.

Exhibit-12.5: Green Tech Market Split, by Technology, in $ Billion



Source: Allied Market Research, BCG Analysis

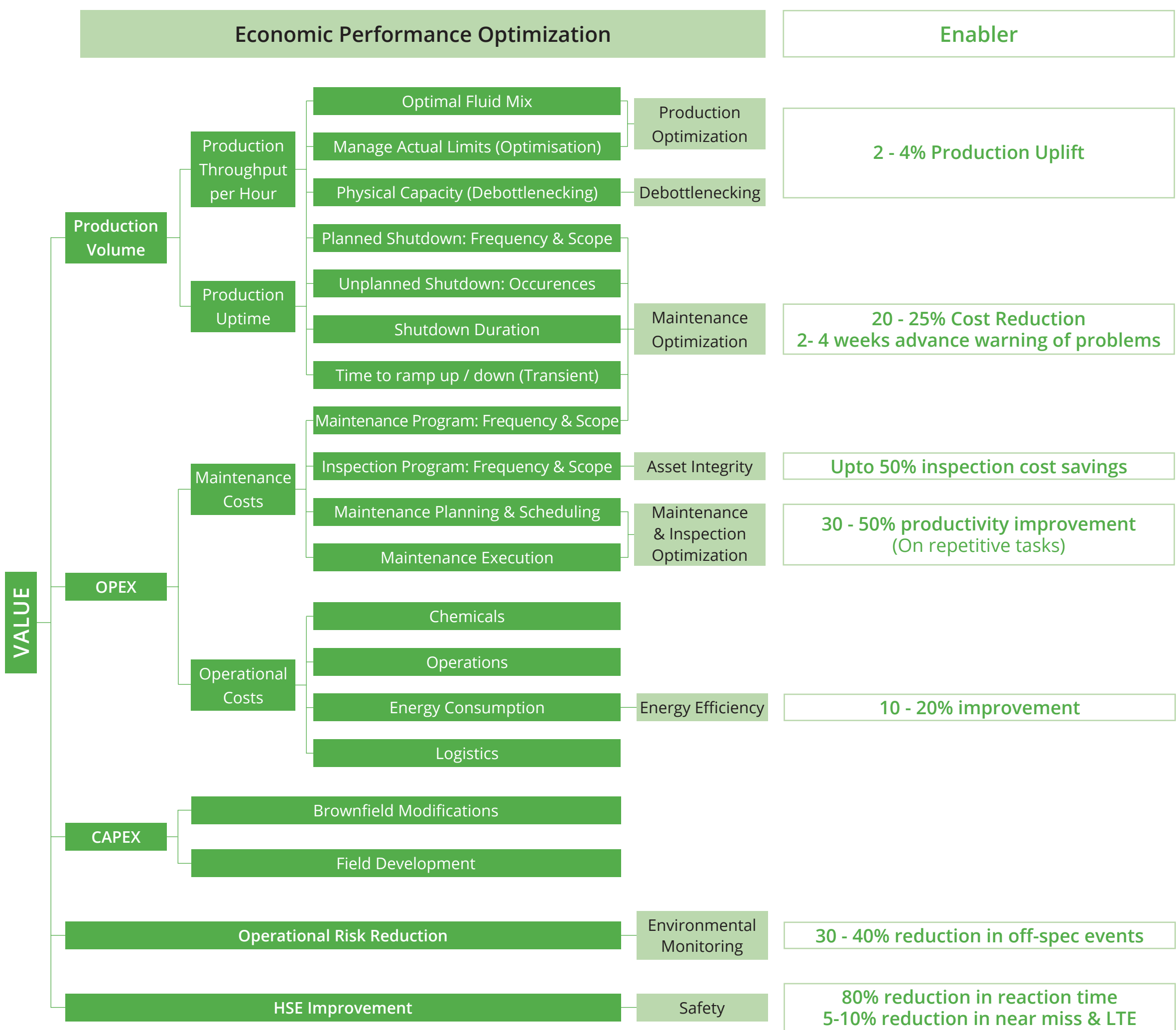
Green Tech is poised to grow at 25-30% CAGR and become a $45-50 Bn global opportunity by 2027

Photo Credit: Adobe Stock

DIGITAL TWIN-ENABLED COMMAND CENTRE

Digital Twins are disrupting project management and are regarded as one of the top 10 strategic technologies that companies want to adopt for improving operations. It involves the creation of a virtual replica of a physical asset thereby enabling visualization of the actual asset conditions. This allows the asset owner to measure and track asset performance, monitor process quality and maintenance lifecycle status. It also enables the simulation of different pre-defined scenarios that can help identify high-risk components and desired production configurations aligned with efficiency & emission goals. Maintenance can be predictive instead of reactive – increasing machine life cycle & efficiency and avoiding unexpected downtimes. Digitizing assets enables the development of an integrated command centre with 360°-degree view of operations to realize significant value across multiple dimensions (Exhibit-12.6). It also helps prevent information loss and speed up handover with new technologies.

Exhibit-12.6: Digitizing assets can help realize significant value



Source: BCG Analysis

EMISSION-LINKED DECISION SUPPORT SYSTEM

Big data & advanced analytics can be leveraged to develop a decision support system that provides real time transparency on the emission & economic implications of each of the key operational parameters. Emission critical KPIs can be prioritized for real-time quantification of value and trade-offs and track adherence to targets. The calculation of the emission and economic impact can be done based on advanced analytics on historical data and effectiveness can be improved with learnings from real-time performance data. A simple control panel screen can empower the ground-teams with real-time data on the impact of their decisions and enable supervisory control at different management levels (Exhibit-12.7), fostering cooperation and alignment to the company's strategy goals.

Exhibit-12.7: Align operations and management with consistent KPIs, linked to emission targets

1 Select KPIs for each plant

2 Link operational KPIs to emissions

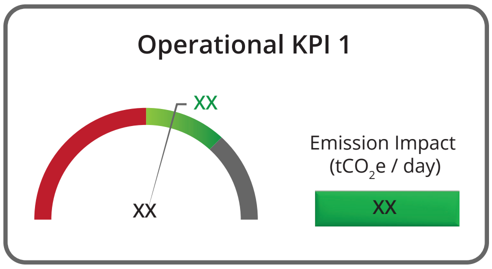
3 Set limits and targets

4 Display real-time information

5 Clear visualisation

Control Panel with a collection of identified KPIs...

... with clear limits defined and impact of change highlighted



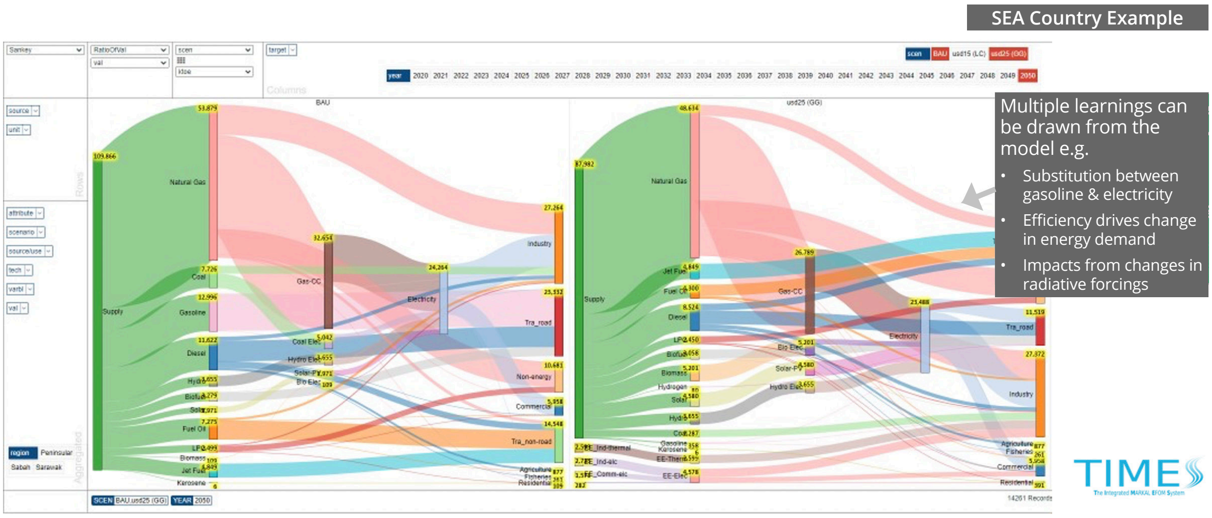
Source: BCG Analysis

ADVANCED ENERGY SCENARIO MODELLING

Linear programming & scenario modeling can provide a comprehensive overview of the energy system and help address resource mix problems & demand elasticities. Models backed by a rich set of inputs can help validate company strategy and guide the path & progress through net zero by combining operational parameters with expected demand & supply scenarios. The TIMES[2] model, developed as part of the IEA-ETSAP (Energy Technology Systems Analysis Program), can compute an inter-temporal partial equilibrium on integrated energy markets with the objective of optimizing the total surplus and energy costs while factoring in environmental and technical constraints (Exhibit 7). The PLEXOS model, by Energy Exemplar, can help achieve rigor testing of detailed power system features, such as system reliability & flexibility and the impact of renewable energy on the system, through high-resolution modeling of the electric power system.

[2] *TIMES – The Integrated MARKAL-EFOM System*

Exhibit-12.8: TIMES modelling of energy system flows provides holistic Southeast Asia country-wide view



Source: BCG Analysis

PARTNER ECOSYSTEM ENABLEMENT

Cross-industry / sector data partnerships enable joint abatement initiatives across the ecosystem. With partners engaged across different stages of the value chain, ETAC can benefit from learnings and best practices across partners through open data collaboration. Richness of insights and effectiveness of predictive analytics employed can be greatly improved by incorporating data from multiple sources and under different operating conditions. Data collaboration also ensures transparency and accountability, enabling period reviews on performance vs targets and implementation of mitigation initiatives in case of any challenges.

CUSTOMER PERSONA IDENTIFICATION & MANAGEMENT

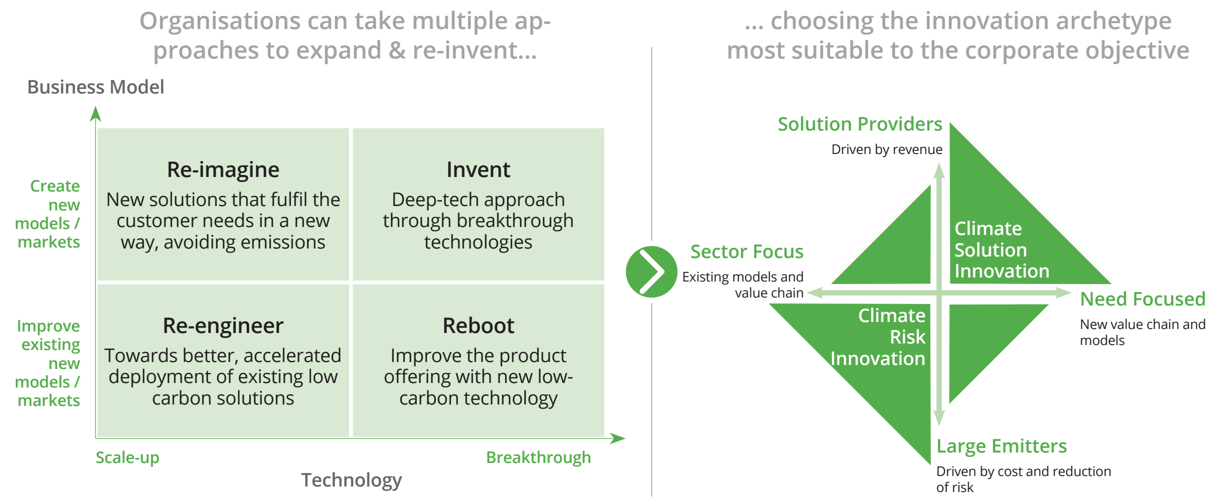
Digital offers major opportunities to manage the relationship with clients through new communication channels, even real-time. Limited data availability and usage of segmented marketing compared to targeted campaigns have made it challenging for O&G retailers to historically capture value from personalization. Building a customer data platform can help analyze customer behavior and purchase patterns to optimize operations. Behavioral analytics can help redefine promotional nudges to incentivize sustainable customer behaviour while fostering customer retention and growth. Multichannel strategy – receipts, mobile, email - can enhance engagement and improve the quality of insights from the platform. A forward-looking and strategic view of how technology and data can be leveraged from the very start before making major commitments of resources, time and energy is a key differentiator for success. This mindset is characterized as "technology eco advantage"[3] —using advanced technologies and ways of working to enable profitable solutions that also have a positive impact on net zero and other environmental, social, & governance goals.

[3] *BCG article "How Tech Offers a Faster Path to Sustainability" by Karalee Close, Norbert Faure, and Rich Hutchinson*

PROCESS INNOVATION

While digital solutions can help extract tremendous potential from the existing portfolio of operations and guide future investments, innovations in process design are critical to hit net zero aspirations. Process innovation can open multiple new opportunities for businesses, investors, and governments. A mindset shift to look at companies as providers of solutions instead of just as a source of emissions can help unlock new opportunities that create business advantage and value while accelerating the climate cause. The focus then shifts to new sources of revenue over significant costs, and the objective moves beyond incremental improvements to transformative business models (refer Exhibit-12.9).

Exhibit-12.9: BCG's Climate Innovation Canvas unlocks business value while accelerating the sustainability goal



Source: BCG Analysis

In some areas, the solutions already exist, however when they are mixed and matched, the results can be dramatically different. For instance, it is widely known that horizontal drilling and fracking have both existed and when used on a standalone basis, these yielded sub-economic results, but their usage together has produced hugely pronounced positive impact for oil and gas production. Re-examining existing solutions and technologies to evaluate the potential to implement them in conjunction or alternatively to produce more desirable results could accrue significant value in terms of abatement of costs or timelines. Abatement & green growth technologies are emerging rapidly across dimensions, targeting efficiency improvement of current systems along with development & optimized utilization of new sources of energy (Exhibit-12.10).

Based on the energy landscape and expected demand, India presents a lucrative opportunity for the following priorities:

EFFICIENCY OPPORTUNITY

Along with re-imagination and invention, re-engineering through energy enhancement programs within the refineries must be explored. Integrated CDU / VDU energy optimizations, low temperature distillation, low grade energy utilization, process intensification, energy optimization in furnaces & heat trains, oxygen enrichment, residual oil hydro-processing, residue pyrolysis, dividing wall column for separation of hydrocarbons and petrochemicals, membrane-based separation of hydrogen, C3 stream, olefin / paraffin and low temperature heat recovery systems like ORC are some examples.

BIOFUELS OPPORTUNITY

Strong technology focus on the development & cost optimization of second generation and advanced biofuels utilizing domestic feedstock is underway. Innovations in the areas of cost optimization of biomass pre-treatment, indigenous development of cellulase enzyme & co-fermenting yeast, value addition technologies on lignin rich residue, efficient utilization of used cooking oil for biofuel production and development of Sustainable Aviation Fuels (SAF) are key value drivers. In SAF, the hydro-processed esters & fatty acids (HEFA) production pathway makes up the largest share of the current market, but processes with higher long-term growth

Exhibit-12.10: Abatement & green technologies on the path to net zero

Efficiency
- Demand-specific identification of drives & energy monitoring
- Expansion of solar thermal energy for heat supply
- Energy Efficiency in...
  - Compressed air generation and applications
  - Pumps
  - Drives through IE3 / IE4 motors and frequency inverters
  - Ventilators
  - Refrigeration Plants
  - Ventilation and air conditioning technology
  - ICT
  - Lighting
  - Compressors
  - Steam Generation
- Savings in process heat through digitalization
- Savings in mechanical energy through digitalization
- Building automation & energy efficiency in heating systems
- Substitution of HFCs etc, in coding & air conditioning
- Heat Recovery
  - Low Temperature Waste
  - Absorption Heat Transformers
  - Organic Rankine Cycle
  - Kalina Cycle
- Furnaces / Boilers
  - Combustion Optimization
  - Oxygen Enrichment
  - Electric Furnaces
- Processes
  - Progressive Crude Distillation
  - Alternative desulfurization
  - Microwave Cracking
- Separation Membranes
  - H_2 recovery and purification
  - Paraxylene Separation
  - Olefin / Paraffin separation
- Alternative uses for Fuel Gas
  - Stripping
  - Co-generation
  - SMR

Thermal Storage
- Molten Salts
- Liquified Air Energy Storage
- Pumped Heat Electrical Storage

Renewable Power
- Wind
  - Onshore Conventional
  - Offshore fixed
  - Offshore floating
  - Emerging (Magiev, Airborne, Bladeless)
- Solar PV
  - Wafer-based
  - Conventional thin film
  - Concentrator
  - Emerging Technologies (Organic, Perovskite,Quantum dot
- CSP
  - Stationary (Flat Plate)
  - Line-focus (Parabolic Trough; Linear Fresnel)
  - Point-focusing (Solar Tower; Stirling Engine)
- Marine
  - Tidal
  - Wave
  - Current
  - Thermal gradient
  - Salinity gradient
- Hydro
  - Conventional Dams
  - Run-of-the-River
- PPA

Energy Storage
- Mechanical
  - Pumped Hydro
  - Flywheel
  - CAES (Compressed Air Energy Storage)
  - Adiabatic CAES
  - Gravity Potential
- Electro-mechanical
  - Lead-acid
  - Li-ion
  - NaS
  - Super capacitors
  - Na-ion
  - NiMH
  - Flow
  - Metallic
  - Li-anode
  - Liquid Metal
- Electrical
  - Capacitors
  - SMES (Super conducting Magnetic Storage)
- Chemical
  - Fuel Cell
  - Hydrogen
  - Synthetic Natural Gas

Waste / Biomass
- Producing biogas via anaerobic digestion of -
  - Agricultural waste
  - Animal waste
  - Organic fraction of Municipal Waste
  - Wastewater sludge
  - Industrial Residue - Pulp Industry (Black Liquor)
  - Industrial Residue - Bagasse
  - Industrial Residue - Food Industry
- Producing Biogas ...
  - from algae
  - via gasification
  - via pyrolysis
  - via Hydrothermal Carbonization (HTC)
  - via Hydrothermal Liquefaction (HTL)
  - via Supercritical Gasification
  - via Enzymatic Fermentation
  - to Bio-methanation via upgrading (compression & liquefaction)
- Valorizing digestate produced via AD as fertilizer
- Valorizing bio-char produced via pyrolysis as fuel / fertilizer
- Converting bio-oil produced via pyrolysis to HVO
- Upgrading biomass properties with pre-treatment
  - Drying, shredding, grinding
  - Pelletisation and Briquetting
  - Torrefaction
  - Pyrolysis
- Burning biomass in
  - Fixed Boilers (travelling, vibrating or step grate)
  - Fluidized bed Boilers (bubbling or circulating)
- Buying Biomethane Certificates (eq. to power PPA)
  - Heat Generation
  - Biomass for Heat
  - Biomethane for Heat
- Power Generation
  - Biomass for Power
  - Biogas for Power
  - Bio-methane for Power

Methane, Flaring
- Associated / Stranded Gas monetization
  - Small-scale / off-grid power
  - Small-scale LNG
  - Mobile / small-scale gas to liquids
- Methane emission maintenance and equipment
  - Vapour Recovery Units
  - Air Controlled Systems
  - Gas Equipment Electrification
  - Enclosed Combustion (with heat recovery)
  - Other Optimized Equipment
- Methane Emissions Leak Detection and Repair
  - Continuous Monitoring
  - Remote Sensing

Hydrogen
- Alkaline Electrolyzer
- PEM Electrolyzer
- H_2 production from...
  - Biogas
  - Bio-methane
  - Bio-methanol
  - Bio-Ethanol
  - Bio-Naphtha
  - Crude Glycerine
- SOEC Electrolyzer
- Anaerobic Digestion
- Pyrolysis / Gasification
- Plasma Reforming
- Supercritical Water Gasification
- Photo-electro Catalysis
- Photo Catalysis
- Thermo-chemical Water Splitting

Renewable Heat
- SHIP
  - Stationary (Flat Plate)
  - Line-focus (Parabolic Trough; Linear Fresnel)
  - Point-focusing (Solar Tower; Stirling Engine)
- Geothermal
  - Thermal Energy
  - Liquid dominated Plants
  - Enhanced Geothermal System

CCU
- Mineralization
  - Aggregates
  - Inorganic Carbonates
- Chemicals
  - Methanol
  - Urea
  - Ethylene
  - Polycarbonates / Polyols
  - Building Polymer Blocks
  - Butanol
- Direct Use
  - Dry Ice
- Feed
  - Algae Biomass
- Fuel
  - Algae Oil
  - Liquid Fossil Fuels
- Novel Uses
  - Carbon Nanotubes
  - Organic Solvent Bacteria
  - Carbon Black
  - CO_2 Fuel Cells

CCS
- Combustion
  - Post Combustion
  - Chemical-loop Combustion
  - Oxy-fuel Combustion
  - Pre-Combustion
- Capture in Specific Units
  - FCC
  - Power Plant
  - CDU
  - SMR
- Transport
  - Onshore Pipe
  - Offshore Pipe
  - Ship Pipe
- Storage
  - Saline Aquifer Onshore
  - Saline Aquifer Offshore

Source: BCG Analysis

potential, like alcohol-to-jet (ATJ) and power-to-X are gaining relevance. HEFA is the best near-term option given existing capacity, but limited availability of low emissions feedstock remains a constraint and costs remain high. ATJ can use two different feedstock types: sugar (e.g., sugarcane) & cellulose (e.g., agriculture residues). The abundance of cheap feedstock, however, is counteracted by the significant CAPEX investment required. Power to liquids (PtL) can be a long-term option, given the lack of feedstock issues. However, it is in the nascent stage and yet to be demonstrated at an industrial scale.

RENEWABLES OPPORTUNITY

With renewable sources being abundant, innovations to ensure maximum capture and utilization for prolonged periods have the capability to drive the most value. Emerging long duration energy storage (LDES) technologies will be critical for supporting the wide scale deployment of renewable energy sources. These systems will provide flexibility in terms of absorbing and managing fluctuations in demand and supply. Substantial development and indigenization of potential technologies along with suitable policy support are required for accelerated deployment. This will also be key for round the clock renewable power availability for process industries to sustain operations.

BATTERY OPPORTUNITY

According to the World Energy Outlook 2021 by the International Energy Agency, the annual demand for lithium-ion batteries in 2040 would be equal to the output of more than 20 times the capacity of today's largest Giga-factory. Building battery recycling and reuse capabilities would be a major opportunity. Battery recycling will be mainly driven by regulation, although economic factors and volume growth will also be important considerations. Pyro-metallurgical and hydro-metallurgical treatment technologies currently exist to scale. However, innovations to reduce energy consumption and control operating costs can help unlock significant potential.

CARBON CAPTURE, UTILIZATION & STORAGE OPPORTUNITY

Currently, most applications of CCUS are not viable. The cost of CCUS ($/MT) is the highest in sectors with dilute CO_2 streams like cement (US $ 72), steel (US $ 79) and power generation (US $ 90 - US $ 100), and it is most competitive in pure-stream CO_2 sources like ammonia and ethanol (US $ 15 - US $ 20).

Innovations for enabling scalable & cost-effective CO_2 capture technology is in demand, with technologies based upon absorption, adsorption, cryogenics, chemical looping etc. The CO_2 captured opens a multitude of new business avenues through the production of value-added chemicals such as methanol, formic acid, urea, polycarbonate/polyol, methane, ethylene, ethanol, butanol, glycerol, petrochemical feedstocks, and polymers. The aim is to build a portfolio of solutions scientifically and economically suited to current conditions and sustainability goals.

Reducing technology costs, increasing demand for captured CO_2, and creating an enabling environment of supporting infrastructure & demonstrated business models are all critical for faster deployment of CCUS technologies.

Coal is not only the backbone of electric power generation, but many major industries like cement, iron and steel, bricks, and fertilizers also consume large quantities of coal. Gasification of coal helps enable the capture of CO_2 prior to the combustion, from the fuel gas mixture, at a relatively lesser cost as compared to the post-combustion CO_2 capture. CCS in gasification projects is considered a promising technology for cost-effective carbon mitigation for deep-seated deposits. Syngas produced from coal gasification is used in producing liquid fuels, Synthetic Natural Gas (SNG), energy fuel (methanol & ethanol, DME), ammonia for fertilizers and petrochemicals.

HYDROGEN OPPORTUNITY

Scale-up of efficient indigenous electrolyzer technologies (viz. membrane-less electrolyzers, Anion Exchange Membrane type etc.) need to be explored to reduce import dependence and to lower costs. This will also open other pathways of green hydrogen conversion to green ammonia & green methanol for ease of storage, transportation, and utilization of green fuels. Direct decomposition of gas to hydrogen and carbon and utilizing the carbon as nanotubes also has high value.

In addition to production, innovations in hydrogen storage & transportation will be required. Due to low density and high flammability, H_2 handling/storage poses major challenges like the requirement of very high pressures cylinders, the potential for hydrogen embrittlement and high capex. Research is required to identify cost-effective novel materials to store the hydrogen. On the other hand, several organizations are working on developing novel processes using ammonia and liquid organic hydrogen carriers (LOHC) as hydrogen carriers. Utilization of hydrogen-enriched compressed natural gas (HCNG), with better fuel economy and lower NOx, CO & CO_2 emissions, as vehicle fuel or in city gas distribution networks has tremendous value. Many institutions have taken field trials of buses and light-duty vehicles using HCNG as fuel. Due to the high potential for emission reduction, further research is required to determine the optimized H_2 / NG (Natural Gas) ratio, metallurgy compatibility, engine tuning and cost optimization in H-CNG utilization.

Hydrogen is promising to become a widely used tool in the transition to green energy pathways through usage in refineries, hard-to-abate sectors like steel etc., through co-located hydrogen production, usage centers. Hydrogen can also contribute through the ammonia route for broader use across the energy value chain, as a storage medium and potentially as fuel for mobility, especially ships.

The technologies to achieve energy transition already exist; but systemic innovation is urgently needed to integrate them into new market structures and regulations, business models, and energy system operations. To achieve our climate targets, therefore, we will need to prioritise certain innovations in key areas of energy, process and the market.

- IRENA

PRODUCTION-LINKED INCENTIVES OPPORTUNITY

Climate action is gaining strong focus amongst the priorities for GOI, the “Panchamrit Commitments” being a testament to the same. Public sector support is critical to encourage innovations across the sustainability spectrum. Production linked incentive (PLI) schemes can be an effective way to drive volumes. Till date, the cumulative government outlay for the scheme is Rs 3 lakh Cr and is expected to attract investments worth Rs 4 lakh Cr across 14 key sectors to create national manufacturing champions.

In renewables, the Government has raised the outlay for solar PV modules to Rs 24,000 Cr in the FY 2022-23 budget after seeing an encouraging response in the first round for the Rs 4,500 Cr scheme. Based on the waitlist from the first round of bidding, it seems like the entire Rs 24,000 Cr PLI outlay would be well covered. A similar demand was visible in the ACC batteries PLI scheme, where the applications were received for ~110 GWh against the 50 GWh PLI scheme. The Government may consider increasing the PLI outlay for this sector on similar lines as for solar PV modules PLI, considering the massive interest.

Similar incentives under the PLI scheme for niche sustainability-related technologies can provide an impetus to local innovation and manufacturing. The Government of India has taken a host of proactive policy measures, including an elaborate set of schemes aimed at channelizing growth of energy transition areas for building domestic production capacity and reducing dependence on imports and local employment. It is hoped that the progress against these shall be constantly measured and the policies shall be modified/supplemented as required over time in sync with the evaluated feedback.

KEY RECOMMENDATIONS

- **Deploy advanced digital tools for emission tracking and mitigation:** Deployment of digital technologies like Digital Twin, Emission linked DSS (Decision Support System), Advanced Energy Scenario Modelling, etc., can help create an integrated ecosystem combining digital and physical assets focused on emission monitoring and reduction.
- **Develop & promote emerging green technologies:** Establish internal process innovation as a priority to develop green technologies by adopting the framework – Re-engineer, Re-imagine, Reboot, or Invent. Promote investment in abatement & green-growth technologies by piloting emerging technologies.
- **Establish coordination framework knowledge sharing and joint accountability:** Set up sectoral bodies to reap the collective benefits of efforts being made by individual entities, enabling the rollout of emerging solutions in an expedited manner with the least cost and with minimal loss of time. International oil & gas players may also be invited as partners.
- **Mobilize investor interest with public sector backing:** Increase public funding via co-investment and matching mechanisms to lower investor risk. The public sector, with due policy and funding support through fiscal measures and/or greater access to green finance, should absorb increased levels of investment risks currently associated with emission reduction technologies (early adoption stages).
- **Use of Production Linked Incentive schemes** for building domestic capacities and helping create global competitive ability. Constant evaluation of the PLIs, timely reinforcement, enhancement and increase in the scope of the PLIs as required through the transition journey. PLIs, as enunciated by the Government of India, can prove to be powerful tools in the transition journey for not only serving local needs but being able to lead in the area of innovation and technology to be supplied at a global scale. It also needs to be ensured that the PLIs act as a catalyst for building domestic capacity but does not result in any hurdles for the new entrants due to any advantages to the incumbents

Photo Credit: Adobe Stock

Chapter 13

GREEN FINANCING

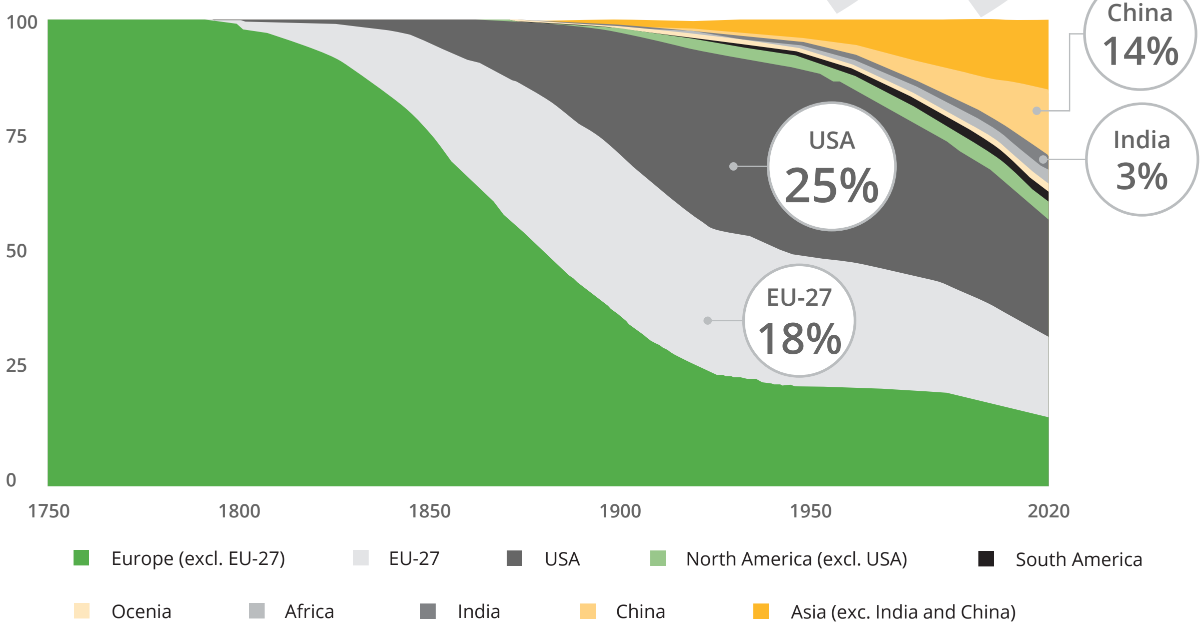
In this section

INTRODUCTION

India is the 5th largest country by GDP and is home to more than 17% of the world's population. India emits 7% of the world's GHG, making it the 4th largest emitter after China, the USA & the EU in 2020. However, to put it in context, India's per capita emissions are much lower than the global average (1.96 TCO_2e vs 6.55 TCO_2e[1]) and about 3-9 times lower than the other super-emitters. Also, India's cumulative contribution to global emissions is just 3.3% since 1750 despite being home to the second largest population in the world (Exhibit-13.1).

Exhibit-13.1: Evolution of cumulative CO_2 emission by world region (%)

India is home to 1/6th of the world's population but historically has accounted for only 3.3% of cumulative global emissions



Note: The 5 regions include United States, Europe, China and Asia (exclusing China and India). Data call outs refer to cumulative emissions as of 2020.

Source: Our World in Data

Indian population demographic is one of the youngest in the world it is only at the beginning of our economic growth journey with aspirations to be a $5 Tn economy by 2025. As per UN in 2019, ~28% of our population is poor, and a significant proportion still lacks access to reliable energy. India's economic growth is likely to be accompanied by investments in infrastructure to provide increased access to energy, water, and transport to our underserved population, all of which will contribute to higher GHG emissions.

India is also the 7th most vulnerable country with respect to climate extremes[2]. Extreme weather events have been increasing over the past decade such as cyclone Amphan in the Bay of Bengal,

[1] *World Bank emissions data*

[2] *Germanwatch 2020*

cyclone Tauktae in the Arabian Sea, landslides and floods in Uttarakhand and Kerala. In response, climate adaptation & resilience investments in early warning systems, climate-resilient infrastructure, improved dryland agricultural crop production, global mangrove protection and more resilient water resources are critical to enabling quality of life for our growing population. Ever higher temperatures in different parts of the world, coupled with severe adverse weather events at higher frequency, intensity and ferocity leaving behind a trail of destruction and losses, are becoming the order of the day.

Given India's historic performance and future growth potential, it forms an ideal candidate for global climate investment. Further, investing in climate action can have benefits beyond averting a climate disaster- as per a WEF study[3]. India alone could create more than 50 Mn net new jobs and generate over $1 Tn in economic value by 2030 by enabling a just transition to a green economy. Climate action will thus be key not just for achieving a world net zero, but also for securing India's economic future.

In essence, India being the largest economy aspiring to higher levels of economic prosperity, the journey to Net Zero will be critical for enabling the achievement of global commitments to climate change and will require a significantly different pathway from developed countries to enable economic growth & increased climate resilience.

Photo Credit: Adobe Stack

[3] *Mission 2070: A Green New Deal for a Net Zero India*

THE TWO STARK REALITIES OF CLIMATE FINANCE IN INDIA

Since 2018, there has been a rapid increase in governmental & corporate commitments towards climate globally and in India. Globally 140 countries, covering 90% of global emissions, 410 publicly traded companies (including climate neutral pledges) and 450 financing institutions representing USD 130 Tn in assets have committed to Global Net-Zero.

India, too has committed to a net-zero carbon emissions target by 2070 with four short term goals viz.

- Reaching a non-fossil fuel energy capacity of 500 GW by 2030
- Fulfilling 50% energy requirements via renewable energy by 2030
- Reducing CO_2 emissions by 1 Bn tons by 2030
- Reducing carbon intensity below 45% by 2030

Significant traction in the Indian corporate sector, with 85+ leading corporates committing to science-based targets to reduce emissions is already seen. In fact, 8 out of the 10 largest companies in India (by market capitalization) have set net-zero goals, with most targeting net zero emissions by 2030. Indian corporates like Reliance, Adani, NTPC, GAIL, Renew Power etc., are also committing significant investments in green projects over the coming decade. All Indian companies in the oil & gas sector are seriously working on their company-specific situations and have their strategies well decked to handle the emerging issues relating not only to transition but across the entire ESG spectrum. In addition, net-zero commitments of global giants like Amazon, LG, and Hyundai are pushing their value chains in India (including MSMEs) towards greener options.

While this is a promising start, we will need significant climate finance to enable India's Net Zero vision. There are several projections about the amount of funds that may be required for a just and orderly transition for the world and various countries. These estimates vary in the specific amount of funds needed. However, these are unanimous in concluding that the fund requirement for energy transition will be huge. As per one such estimate[4], as below, it has been projected that $10 Tn will be required to fund India's 2070 net zero scenario, with a currently projected financing gap of $3.5 Tn and catalyzing climate investments, particularly by and in the private sector will be key to bridging this gap (Exhibit-13.2).

Exhibit-13.2: The Indian Green Financing Ecosystem is in early stages, urgent scaling-up of finances needed

While green capital[1] raised in India is growing, but it is a fraction of the global capital

Green Capital raised in 2019

India[2]	$21 Bn Highest ever
World	-$1 Tn

>

Significant capital shortfall anticipated in India's target to achieve net zero by 2070

Estimated Funds needed	>$10 Tn
Expected Shortfall	~$3.5 Tn

[1] Including debt, M&A and Equity Funding

[2] $15.7 Bn by Bank of America alone

Source: Business Standard; World Economic Forum; Council of Energy, Environment and Water

[4] CEEW: Council on Energy, Environment & Water

India's green financing landscape has two opposite realities affecting climate investments today.

REALITY-1: INDIA NEEDS 9 TIMES MORE CLIMATE FINANCE ANNUALLY

India's climate finance flows in 2019 were US$21 Bn. However, the projected annual funding need is more than US$170 Bn. India requires nine times more climate investment to meet our climate ambitions, and there is a need to scale this funding urgently, particularly given the large up-front costs estimated with decarbonization of sectors such as power, oil & gas, steel and cement.

India's Climate Finance Landscape

1 Domestic sources are driving climate finance; limited foreign capital inflows despite public commitments from developed countries

85% of climate finance was from domestic sources like commercial banks, government budgets and public sector grants. India has so far received less than a fraction of the global climate finance flows, despite commitments from developed countries to provide US$100B of climate finance annually to developing countries like India and an excellent track record of the country in following up on its commitments so far.

2 Limited maturity of financial instruments; high reliance on debt and grants

More than 60% of finance flows were in the form of loans from commercial banks and multilateral organizations. Government funding was primarily offered via grants.

3 Funds are primarily directed towards renewables, limited funding for climate adaptation and low carbon mitigation technologies

Climate funding is majorly towards renewables, with the power generation sector remaining the primary recipient with ~80% of funds. Other low-carbon pathways, such as biofuels & last-mile technology like CCUS and green hydrogen, have yet to receive enough funding. Sustainable transport – primarily large metro projects received a significant share of bilateral & multilateral financing. Adaptation funding was critically underserved, with less than 10% of overall funds.

India needs heavy investment to grow its renewable energy capacity to 500GW. It also needs infrastructure investments in building out our cities. Further, to achieve our net zero aspirations, the following areas need focused funds flows:

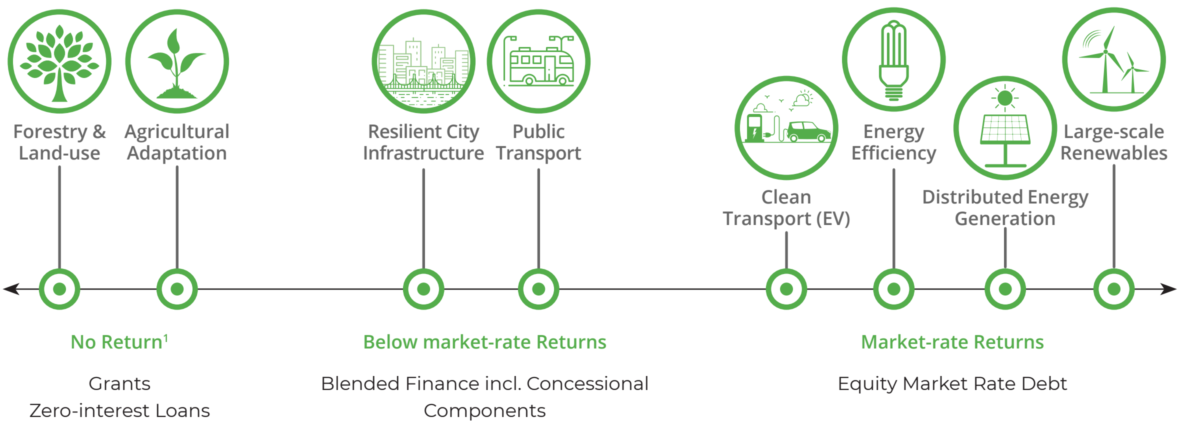
- Building new power transmission infrastructure
- Investing in affordable energy storage technology
- Low carbon technology for hard to abate sectors
- Improving energy efficiency at scale
- Sustainable agriculture, water & food security
- Resilient city infrastructure
- Adaptation & resilience

REALITY-2: LACK OF A BANKABLE PIPELINE OF PROJECTS IN INDIA FOR INVESTORS

Innovations that switch to being adopted and funded at scale typically do so when it is environmentally and economically viable. For example, in 2007, power from solar plants was much more expensive than from traditional sources. State subsidies and grants led to early adoption, but it was only when solar achieved grid parity that adoption took off. 2/3rd of India's solar capacity has been built over the last 5 years, with funding coming in from domestic and international investors at competitive prices.

Technology areas other than renewables, viz. low carbon technologies for hard-to-abate sectors, energy storage, sustainable agriculture & climate adaptation, have yet to be proven commercially viable and are therefore considered less bankable (Exhibit-13.3).

Exhibit-13.3: Bankability of Climate Change opportunities vary



[1] *However, with carbon markets evolving, increasing potential for some returns via offsets*

Source: BCG Analysis

For innovations to become bankable, governments have an essential role to close this investment gap through the provision of fiscal incentives that drive economic viability. The consistency and enforcement of these incentives are what would drive bankability. These projects also face a few other challenges in getting funding such as:

1. **Lack of a standard definition of "green"** in India resulting in limited visibility on fund flows, project end use and thereby increasing fears of green-washing
2. **Limited incorporation of climate risk in credit rating/ risk frameworks** resulting in higher perceived risks of green investments
3. **Long term institutional investors such as insurers and pension funds** are not factoring climate risks in investment portfolio
4. **Lack of mature climate financing instruments & market mechanisms** that factor in carbon pricing and help de-risk climate investments

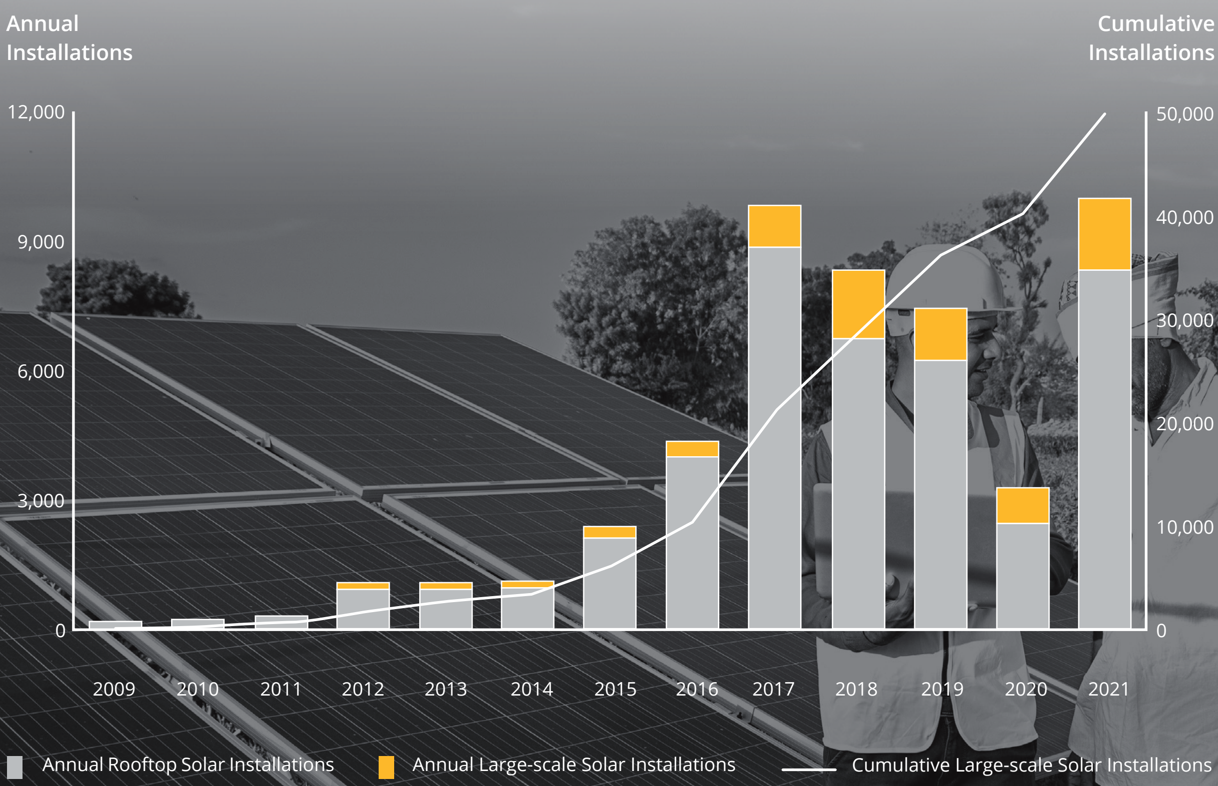
CASE STUDY:
INDIA'S SOLAR ENERGY JOURNEY

An exemplar of catalyzing climate finance

In 2010, India launched the National Solar Mission, with objective of being a global leader in solar energy by creating the policy conditions for rapid solar technology diffusion across the country. The mission achieved its initial target of 20,000 MW of grid connected solar power by 2017 – five years ahead of time, this target was subsequently revised to 100,000 MW by 2022 (Exhibit-13.4).

In this report, an attempt has been made to enlist the key initiatives that enabled the solar success story. This list is non-exhaustive but is a good representation of various parameters that need to emerge / co-exist to enable adequate capital flows to low carbon technologies.

Exhibit-13.4: Indian Solar Installation (MW)



Source: Mercom India Research (Dec 2021)

[5] *CEEW: Council on Energy, Environment & Water*

Photo Credit: Adobe Stock

MAJOR DRIVERS BEHIND THE SUCCESS OF SOLAR IN INDIA

The below described five initiatives in tandem were the. While there were implementation hurdles and initiative associated criticism, they were in the right direction and provided rich learnings for India, and this case provides an excellent reference base as the country devises a Climate Finance policy.

1 Setting an implicit price on carbon, increasing affordability of clean energy

India put in place a nationwide carbon tax on coal under the Clean Energy Tax, fossil fuel subsidies for oil & gas were reduced over a period of time from $ 30B in 2014 to $9B in 2019[5] . Subsidies in this context include direct and indirect transfers, foregone revenue, and provision of goods or services below market value and income and price support through regulations. Further, Renewable energy certificates (REC) were launched in 2011 as a market mechanism to enable the tracking and trade of renewable energy.

2 Introducing a legal framework to promote renewable energy

Electricity Act 2003, National Electricity Policy, 2005 and the Tariff Policy 2006 set guidelines and regulations to promote preferential tariffs for renewables to make them cost competitive and to create stable demand by mandating a minimum percentage of energy consumption via renewable energy for states. In addition to the central legal framework, states like Rajasthan, Gujarat and Karnataka have introduced their own solar policies with specific guidelines, capacity targets and preferential tariff models

3 Leveraging fiscal incentives to encourage investment in solar power

India promoted renewables through several fiscal incentives, including taxation incentives such as accelerated depreciation, tax waiver for eligible projects, opening the sector for 100% FDI, and budget allocations such as the Production-linked incentive (PLI) scheme for solar companies. allocations such as the Production-linked incentive (PLI) scheme for solar companies.

4 Reducing the risk and improving the commercial attractiveness for solar

a. Bundling of expensive solar power with conventional coal-based power was used to reduce the cost of power supplied to the utilities. Special procurement mechanisms & Viability Gap Funding (VGF) too enabled a lowering of price

b. Guaranteed offtake mechanisms were created to de-risk solar projects for instance - Solar Energy Corporation of India (SECI) signed 25 years power purchase agreements with solar park developers reducing producer’s risk

c. Supply price reduction via Utility auctions - Reverse bidding was introduced as the market-oriented procurement mechanism as against the practice of feed-in tariff and capital subsidies.

5 Catalyzing investment via public capital infusion

Strategic public capital infusion designed to de-risk investment encouraged a large volume of private investment over time. These included initiatives such as:-

a. Signaling & guidance for banks & lenders via RBI’s inclusion of renewable energy in priority sector lending, guidelines for rooftop solar lending by the Department of Finance

b. Infusing patient long term capital via tax free infrastructure bonds valued at US$ 800 Mn for financing RE initiatives through 2015 and 2016

c. Concessional loans & multilateral grants from World Bank and Asian Development Bank (ADB) were made available to State Bank of India and Punjab National Bank for solar rooftop projects

CLIMATE FINANCE ACTION PLAN FOR INDIA

STEPS FOR CATALYZING CLIMATE FINANCE

1
Create the policy & regulatory environment to encourage climate investments

2
Clearly define a green taxonomy and climate risk framework for low carbon development

3
Targeted investment to catalyze private & multilateral investors

The illustration in Exhibit-13.5 details the various government and policy initiatives that can help drive climate finance in India.

Exhibit-13.5: Climate Finance Strategy

Climate Finance Strategy

Policy & Regulatory Mechanisms	Robust & intl. aligned framework for low carbon development	Catalyze Private & Multilateral Investment
1 Carbon Pricing	**3 Clear definition of Green**	**5 Clear definition of Green**
Carbon Taxes	Green Taxonomy (aligned to NDCs and international standards)	Project blended Finance
Compliance Carbon Markets	Disclosure & reporting norms	Credit Guarantee / First loss lending
Internal Carbon Pricing	**4 Climate Risk Frameworks**	Patient long-term capital
Fuel Subsidy Reduction	Climate Risk Framework	Direct investment to demonstrate viability
Carbon Border Tax Adjustment	Financial Market Regulations	Priority sector lending
2 Fiscal Policy	Investor Guidelines	Strategic Partnership
Climate Tax Incentives	Climate Risk Guidelines for pensioners & insurers	R&D Funding
Green allocation in budgets	Green Asset Regulations	Incentives for low carbon & climate resilient goods
FDI & ECB norms		Green government Securities
Sectoral policies & incentives		

Climate finance instruments and market mechanisms including Carbon Markets

Awareness, advocacy & capacity building

Climate Data & Intelligence

Governance, reporting & oversight

Source: BCG Analysis

KEY RECOMMENDATIONS

Establish a legally enforceable price on carbon

RECOMMENDATION-1

Move towards establishing an enforceable price on carbon via a combination of mechanisms, including carbon taxes, internal carbon pricing, and introducing a compliance carbon market mechanism in accordance with Article-6 of the Paris Agreement by creating a short term, medium term and long-term plan for sectoral coverage under an ETS.

Carbon dioxide and other GHGs cause negative externalities (indirect costs to individuals and society) that are not sufficiently priced into the market. This has led to a systemic market failure, wherein the true cost of products and services is not fully accounted for and hence not paid for. These unpriced externalities are unevenly distributed across economic sectors and regions, leading to significant market inefficiencies and distortions. As a result, there is an uneven playing field between low-carbon and high-carbon activities.

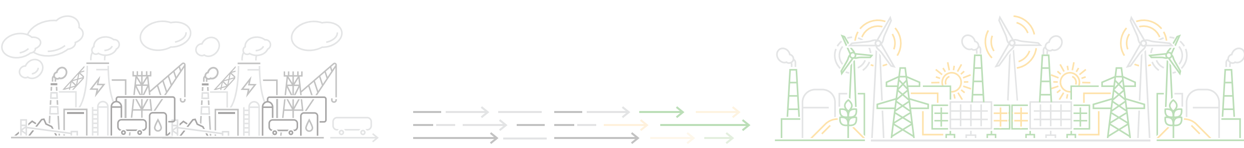
In the absence of a levelling mechanism such as a carbon tax or compliance carbon markets, capital will continue to flow to fossil fuels which are inherently cheaper with efficiencies built in from decades of investment & research.

The lack of a stated cost for carbon also leads to the often-cited symptoms of a sub-scale climate finance market, such as a limited pipeline of bankable projects, challenged economic viability for projects, higher risk levels, the inability of the Banking and Capital Markets sector and the real economy to effectively manage the risks and opportunities arising from climate change—as well as efforts to avoid it.

Governments can enforce a price on carbon by using instruments including carbon taxes, compliance markets, reducing fossil fuel subsidies, internal carbon pricing and carbon border tax adjustments. Fundamentally, the objectives of all these measures are the same, i.e., to enhance the commercial attractiveness of 'green' alternatives. Along with lowering emissions, carbon pricing can improve energy and industrial efficiency, create conditions for technological upgradation and beading out inefficient technologies, limit reliance on imported energy, promote cleaner air, protect and regenerate landscapes, and provide a valuable source of government revenue.

Carbon Taxes / Compliance Carbon Markets

The IMF has stated that limiting global warming to 2°C or less requires ambitious policy measures, such as an immediate global carbon price that would rise rapidly to \$75 -\$100 per tonne of CO_2 in 2030. This can be accomplished using one of two methods: a cap-and-trade system or a carbon



tax charge. The first method, also known as a compliance carbon market, puts a cap on the total emissions that industries can emit and allows those with low emissions to sell their extra allowances to larger emitters, thereby creating a marketplace for greenhouse gas emissions.

India does not have a cap & trade market, though it does have an array of schemes and taxation mechanisms that put an implicit price on carbon, such as Coal Cess, Perform Achieve Trade schemes and Renewable energy certificates. However, the average price of carbon from these initiatives is low (~US$15 as per OECD), and this covers less than 60% of our overall emissions, especially in hard to abate sectors.

Article 6 of the Paris agreement encourages countries to voluntarily cooperate to allow for a globally aligned price for carbon, accounting for the true, social & environmental cost of carbon, thereby enhancing the transparency of economic decisions. While adopting a globally aligned price for carbon is necessary, for developing countries like India, this price should consider the social-economic differences and transition pathways. India cannot immediately afford to set the high carbon price recommended by the IMF due to the pressing need for a just transition of our coal-dependent, low-income population since they spend a higher proportion of their incomes on energy-intensive goods and services. Further, there is fear that higher domestic prices for carbon-intensive goods will make the Indian industry less competitive in global markets.

The subject relating to carbon taxes. Carbon pricing compliances and trading with other related aspects have been dealt with at length in a separate section.

Internal Carbon Pricing

Internal carbon pricing is a strategic planning tool that enables corporates to manage climate-related business risks and prepare for the transition to a low-carbon economy. It allows carbon considerations to become central to business operations and helps de-risk businesses against future carbon prices. It also enables businesses to create pathways to achieve their Net Zero ambitions.

Globally as per CDP, a non-profit organization that runs the world's environmental disclosure system - nearly half of the world's 500 biggest companies are now factoring this type of carbon accounting into their business plans. CDP's analysis found that the median internal carbon price disclosed by companies in 2020 was USD 25 per metric ton of CO_2; this price is expected to rise significantly, given increasing global carbon prices.

In 2021, 85 Indian companies either used or are planning to use an ICP. This is a 50% increase in numbers from 2020, and with growing Net Zero commitments and corporate action, we expect this trend to continue.

India should consider introducing guidelines & disclosure requirements to promote a wider acceptance of carbon pricing for corporates, governments, and other organizations.

Addressing fossil fuel subsidies

Fossil-fuel subsidies are a key financial barrier hampering the world's shift to renewable energy sources. Each year, governments worldwide pour around half a trillion dollars into artificially lowering the price of fossil fuels — more than triple what renewables receive. The International Energy Agency (IEA), in a 2021 report laying out a roadmap to the world with net-zero carbon emissions, stated, "In the next few years, all governments need to eliminate fossil fuel subsidies."

As per IEA, India's energy demand is expected to rise between 35-50% from 2019 to 2030, the highest across all countries. Over the past few years, the Indian government has taken significant steps to provide all Indian families with electricity and cooking gas connections. Still, adopting these modern and clean energy sources remains a big challenge. This is compounded by the fact that a large portion of the population can't afford clean fuel. Transition fuels such as Natural Gas and building transmission & distribution networks are critical to improving quality of life.

While India must have a roadmap for the gradual phase-out of fossil fuel subsidies in Net Zero roadmap – it is critical to ensure that there is a just transition and that it doesn't impact the ability of lowest income households to improve their standard of living.

Carbon Border Tax Adjustment

The uneven application of carbon pricing internationally leads to the potential issue of carbon leakage, wherein industries relocate to countries with less-ambitious carbon policies, thereby increasing that geography's contribution to GHG emissions. A mechanism to prevent and limit carbon leakage from relocating industries to countries with less-ambitious carbon policies is the introduction of border carbon adjustment mechanisms.

For example, as per the EU Green Deal's proposal on such a mechanism, "Europe's efforts to go climate-neutral by 2050 could be undermined by lack of ambition by our international partners. This would mean a risk of carbon leakage. This occurs when companies transfer production to countries that are less strict about emissions. In such case, global emissions would not be reduced. This new mechanism would counteract this risk by putting a carbon price on imports of certain goods from outside the EU."

While carbon border adjustment mechanisms have a strong theoretical basis, their implementation is expected to be challenging, particularly concerning developing countries like India. Let us consider the implications of the EU border tax on India. For instance, EU carbon border tax will initially apply to products from a limited number of sectors, namely cement, electricity, fertilizers, iron and steel, and aluminium in a phased manner from 2026. India is an exporter of several carbon intensive goods such as aluminium, iron & steel. In fact, the European Union is a key export market for India, with USD 33 Bn of exports in 2020 (11% of which were base metals & minerals, including iron & steel). Thus, with the Carbon Border Adjustment Mechanism, Indian goods will run the risk of becoming less competitive in the EU market due to the financial and administrative burden. The UNCTAD forecasts that India will lose USD 1-1.7 Bn in exports of energy-intensive products such as steel and aluminium.

KEY FOCUS AREAS FOR INDIA

1. Introduction of a domestic carbon price
2. Commencement of bilateral negotiations with developed nations like the European Union to ensure mechanisms are designed in a manner that accounts for potential differences in transition pathways between countries. Proactive engagement at global scale is likely to help India negotiate a better position which can enable it transition with least financial burden using this opportunity to its advantage.
3. India should strongly take up the issue of the flow of international funding committed by developed nations to push energy transition efforts worldwide. Despite commitments to contribute USD 100 Bn annually, no financing has flown in towards energy transition. Further, the loans should not be counted as part of the contribution. As such, it is critical that this transition funding takes a character of a legally forcible obligation against the developed nations.

RECOMMENDATION-2

Enforce fiscal policies including tax incentives for low carbon technologies

Promote low carbon technologies with incentives such as PLIs

To achieve India's Net Zero ambition, a critical enabler will be climate finance. India should translate existing Net Zero & short-term commitments into conducive framework conditions, such as national and regional environmental and industrial policies, to support acceleration in climate finance market.

Several low carbon technologies needed to achieve Paris Agreement targets still need to achieve commercial viability threshold, creating a barrier for commercial lenders and investors to provide the necessary capital to grow and scale them. For example, Green Hydrogen and CCUS are often not commercially viable technologies without a sufficiently high carbon price. They are, however needed for decarbonizing several sectors (including Power, Iron & Steel, Chemicals, Light / Heavy Road Transport, Aviation, Shipping, and Buildings, among others).

As in the case of the National Solar Mission, initial government support for renewable energy, such as wind and solar, has helped the industry flourish to the point that these technologies are now among the cheapest energy sources. Specific government incentives are needed to support the development of these cross-cutting decarbonization solutions.

MAJOR AREAS OF WORK

1. **Scaling budgetary allocation & grants** for early stage decarbonization technologies such as Green Hydrogen, CCUS, battery storage, etc. to accelerate commercial viability

2. **Implementing medium-term taxation subsidies** such as investment tax credits or accelerated amortizations in technology investments that have high upfront investments and longer payback periods to make these investments more economically viable

3. **Preferential FDI norms:** To encourage foreign capital mobilization towards proven low carbon technologies

4. **Introduce government schemes / initiatives** based on sectoral decarbonization roadmaps

Define a green taxonomy and disclosure framework in India

RECOMMENDATION-3

Enable more precise tracking of finance flows to green sectors, which, in turn, would help design effective policy, regulations, and institutional mechanisms directed towards increasing both public and private investments in green sectors.

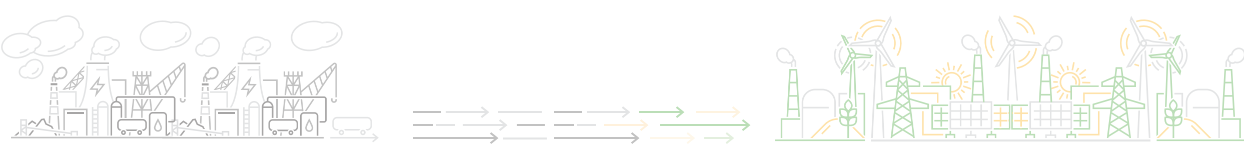
India has committed to going Net Zero in 2070. However, translating this long-term target into sector & state specific definitions of "green activities" and corresponding budgets and pathways is crucial. The transition pathways, carbon targets, and technologies vary not only by sector but also by region, as these are influenced by several factors, including the state of development of the region's economy and the trade-offs to be made versus other UN Sustainable Development Goals (e.g., socioeconomic development).

Financing & lending activity remains constrained today due to uncertainty, firstly due to lack of specificity as to which economic activities can be considered sustainable and secondly due to the projected low financial return profiles for key sectors, projects & technologies. A formal definition of Green Finance in India and clearly understood taxonomy would increase precision in tracking financial flows to the green sectors. This would help design effective policies, regulations and institutional mechanisms directed to increase public & private sectors' green investment.

The European Union has taken significant steps in this direction by creating the EU Taxonomy, which incorporates metrics and thresholds on a sector-by-sector basis. The taxonomy is a 'living' list of all economic activities that can genuinely be considered as a reference of what environmentally sustainable means, defining and providing a shared understanding of what is 'green'.

CREATING A GREEN TAXONOMY FOR INDIA WILL HELP ACCOMPLISH 4 KEY OBJECTIVES

1. Improve climate investment flows to priority sectors as per Nationally Determined Contributions
2. Increase market confidence by avoiding green-washing with specific metrics & criteria for measurement & reporting
3. Improve tracking, disclosure & monitoring of sectoral investment
4. Enable development of policies, incentives for sustainable finance



India's green taxonomy should enable a common definition and set of principles concerning what constitutes climate finance. This should be translated into sector- and region-specific taxonomies that are comparable, flexible for evolution in response to technological and scientific developments and include climate-related performance indicators and targets that correspond to our Net Zero ambition. It is important that India's taxonomy is based on common global principles to encourage foreign capital, but it must consider a number of unique economic & social factors impacting the country.

UNIQUE SOCIO-ECONOMIC CONSIDERATIONS FOR INDIA

1. Indian taxonomy needs to be aligned to NDCs and focused not just on climate mitigation but also on climate adaptation & pressing environmental concerns including:
   - *a. Sustainable agriculture & livestock*
   - *b. Food & Water security*
   - *c. Safeguarding mountainous & coastal ecosystems*
   - *d. Pollution control measures*
   - *e. Disaster management*
   - *f. Building resilient cities etc.*
2. Need focus on transition activities that require significant funding like natural gas, nuclear energy and not just zero carbon activities
3. Minimize administrative burden, focus on a core set of decision metrics. Compliance requirements from taxonomies such as the EU might be significantly high for small scale businesses such as MSMEs (Micro, Small and Medium Enterprises), which account for over 30 percent of India's GDP, employ about 11 crore people and constitute nearly 40 percent of total exports. Some aggregation may help develop such situation-specific metrics.
4. Taxonomy needs to be objective & algorithmic to enable clarity & measurement
5. Indian taxonomy should not focus on particular technologies but rather on technology-agnostic technical screening criteria for commercial activities spanning high-impact sectors such as power, manufacturing, transport, and others. Committing to few specific technologies may not be in a medium or long-term interest.

Photo Credit: Adobe Stock

RECOMMENDATION-4

Incorporation of Climate Risk in Government & Financial sector frameworks

A green taxonomy for India needs to be enforced/ supported with the integration of climate into key risk frameworks to ensure climate risks, both physical and transition, are appropriately priced into the cost of capital, in particular for legacy carbon-intensive activities.

The Prudential Regulation Authority (PRA) in the UK requires banks, insurers and other financial institutions by 2021 to “address the financial risks from climate change through their existing risk management frameworks, in line with board-approved risk appetite, while recognizing that the nature of the risks requires a strategic approach.

In India too, the Reserve Bank of India has committed in 2021 to integrating climate-related risks into financial stability monitoring as well as exploring the use of climate scenario exercises to identify vulnerabilities in the central bank-supervised entities as a part of the Network for Greening the Financial System (NGFS), a grouping of 114 central banks around the world.

Ensure climate risks, both physical and transition, are appropriately priced into the cost of capital

INITIATIVES INDIA CAN TAKE TO BEGIN MEASURING & INCORPORATING CLIMATE RISKS IN DECISION-MAKING

- **Incorporation in credit rating mechanism**

  Current rating mechanisms do not adequately consider the cost of carbon emissions and the climate related risks / benefits associated with projects under evaluation. There is a need to develop a rating system for loans, bonds & other instruments that considers both carbon emissions (per unit capital) and positive externalities from sustainable financing to enable a systemic shift in funding towards more climate positive projects.

- **Introduce mandatory disclosures**

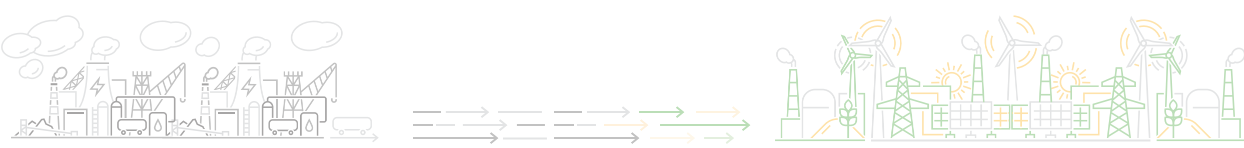
  Mandate corporate & public sector disclosure requirements, including financially material and decision-relevant data relating to climate risks and opportunities. India should adopt disclosure norms consistent with global frameworks, such as TCFD, to strengthen transparency and comparability of climate data for global investors.

- **Inclusion in existing risk assessment frameworks**

  Current risk assessment norms such as Basel-III do not adequately capture climate risks in assessment of an obliger’s ability to repay a loan in compliance with environment safeguard laws. Basel-III also discourages longer-term funding and illiquid investments, which contribute to either increasing lending rates or constraining capital allocation for climate investments. It is recommended that existing risk assessment frameworks incorporate financial risk arising from climate change to help increase capital flow to climate positive projects.

- **Introduce norms for institutional investors like pension funds, insurers**

  Regulations aimed at inclusion of climate risks when identifying eligible investment projects could help channel patient long term capital towards sustainable investments.



De-risk climate finance via strategic public capital infusion

RECOMMENDATION-5

Catalyze investment from private sources of capital. Create a strong legal framework and governance structure for climate finance to centralized accountability and oversight.

There is often a mismatch between capital providers' risk profile and eligible climate projects. There is an urgent need for forms of capital to effectively de-risk investments in climate action to catalyze investment from private sources of capital.

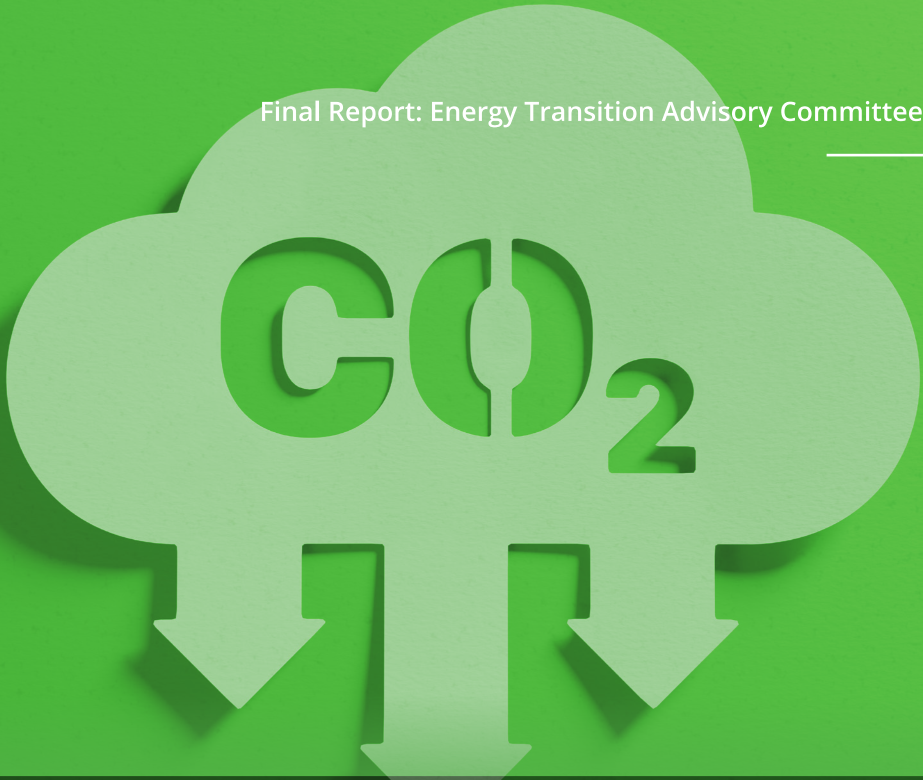
In some sectors, considerable technology and policy risks are associated with early-stage decarbonization technologies and uncertain technological pathways. For example, in Aviation, it is unclear as to what extent sustainable aviation fuels (SAFs) will be used for decarbonization—and which specific SAF (e.g., HEFA-based biofuel versus synthetic fuels) will be dominant. Similarly, it isn't yet clear how the future market will be divided between BEVs and hydrogen fuel-cell vehicles in Heavy Road Transport. Financing of climate action in emerging markets like India is further constrained by currency and political risk factors.

In addition, several projects are not yet at scale and are small in numbers, e.g. distributed energy generations, leading to a lower overall volume of capital flow and need. This introduces barriers to attracting investors, particularly institutional investors that look for minimum ticket size in deals.

Exhibit-13.6: Five archetype investment barriers that catalytic public finance can address

Archetype	Barriers to Investment	Catalytic Finance Instruments	Typical Sectors
Unproven Markets	▪ Concerns about commercial viability of sector in given market	▪ Direct investment (concessional or commercial) to demonstrate viability	▪ Large-scale renewables ▪ Energy Efficiency ▪ Clean Transport
Sub-scale Investments	▪ Projects too small-scale for larger investors leading to high transactional cost	▪ Financing facilities aggregating smaller projects into one opportunity ▪ Securitization	▪ Distributed energy generation ▪ Energy Efficiency
Unattractive risk-return profile	▪ Construction Risks ▪ Off-taker / development risks ▪ Regulatory / currency risks	▪ Loan / Guarantees / First Loss ▪ Political Insurance Loss ▪ Local Currency Hedges	▪ All (in emerging economy context)
Inherent below-market rate returns	▪ Revenues need to be subsidized ▪ Climate change benefits (avoided losses / ES benefits) not factored in	▪ Subsidies ▪ Green Bonds (issued by DFIs / public sector, catalyzing private capital)	▪ Public Transport ▪ Climate-resilient Infrastructure ▪ Agriculture Adaptation
No Return	▪ Financial disincentives (e.g. higher return on deforestation than afforestation) ▪ Climate benefits not monetized	▪ Grants *(For 'no return' sectors, Public investments unlikely to catalyze private sector investment - instead, policy / regulation is needed)*	▪ Forest & Land-Use ▪ Agricultural Adaptation

Source: Climate Policy Initiative, Climate Finance Leadership Initiative, expert interviews



RECOMMENDATIONS ON HOW INDIA CAN CHANNELIZE PUBLIC SECTOR FINANCE TO CATALYZE CLIMATE INVESTMENT

1 **Promote direct investment in commercial projects to demonstrate viability** e.g. Fixed price offtake agreements with green hydrogen plants via public sector enterprises.

2 **Adopt project blended finance** with multilateral agencies to drive investment in projects such as Agri-tech.

3 **Mobilize directed priority sector lending for sustainable finance** via regulatory prescription for minimum investments & preferential capital norms for identified priority low carbon technologies/ sector specific projects for banks & financial institutions. We could also consider interest subvention to subsidize financing of low carbon technology projects etc.

4 **Provide credit risk guarantees / First loss lending:** A major barrier for climate financing is perceived higher risk profiles. Credit guarantees on loans, bonds from banks, setting up of a risk sharing facility for high priority projects can help catalyze investment.

5 **Issue of green government securities:** The Indian government in the latest budget committed to issuing INR 24,000 crore as green government securities. The proceeds from these securities should be directed towards viability gap funding for low carbon technologies, adaptation projects etc. The attractiveness of these instruments can be enhanced with fiscal benefits for investors like capital gain benefits.

6 **Incorporate a nationalized green bank:** Similar to how ICICI created a development financial institution for providing medium-term and long-term project financing to Indian businesses setting up an institution/ mechanism to invest in medium-term and long-term financing for priority projects involving low carbon technology, e.g., Project finance for Green Hydrogen projects needs to be considered.

7 **R&D Funding & incentives for Low carbon & climate resilient goods**

Photo Credit: Adobe Stock

Chapter 14

CARBON MARKET & PRICING

In this section

INTRODUCTION

Economic growth is invariably associated with energy consumption, which has many adverse effects, including carbon emissions. Carbon emissions cause global warming and are therefore responsible for climate change. They also have ill health effects on human beings, with more and more people suffering from respiratory illnesses. Carbon emissions have a huge social cost and put a responsibility on society to reduce them. Various projects with this objective are being implemented worldwide; however, many are not economically viable. An instrument called carbon credits has evolved to balance economic viability with the potential to contribute towards the reduction of carbon emissions.

One carbon credit is equivalent to one metric ton of CO_2 or equivalent GHG emission avoided / removed, which would have occurred in the absence of the project. All GHGs are converted into their respective carbon dioxide emissions levels and are accounted for by the issue of carbon credits.

ELIGIBILITY OF EMISSION REDUCTION PROJECTS - CORE QUALITY CRITERIA

1 ADDITIONALITY

Emissions reduction that would not have occurred in the absence of the activity (resulting in generation of carbon credits) as a result of some other activity under BAU scenario. Also, the activity would not have come up as a result of direct government intervention or business profitability

2 PERMANENCE

Emissions reduction or removal cannot be reversed in the future

3 LEAKAGE

Emissions are not truly reduced and could have been displaced to other locations

4 ACCURACY

Credits are issued based on actual emissions reductions

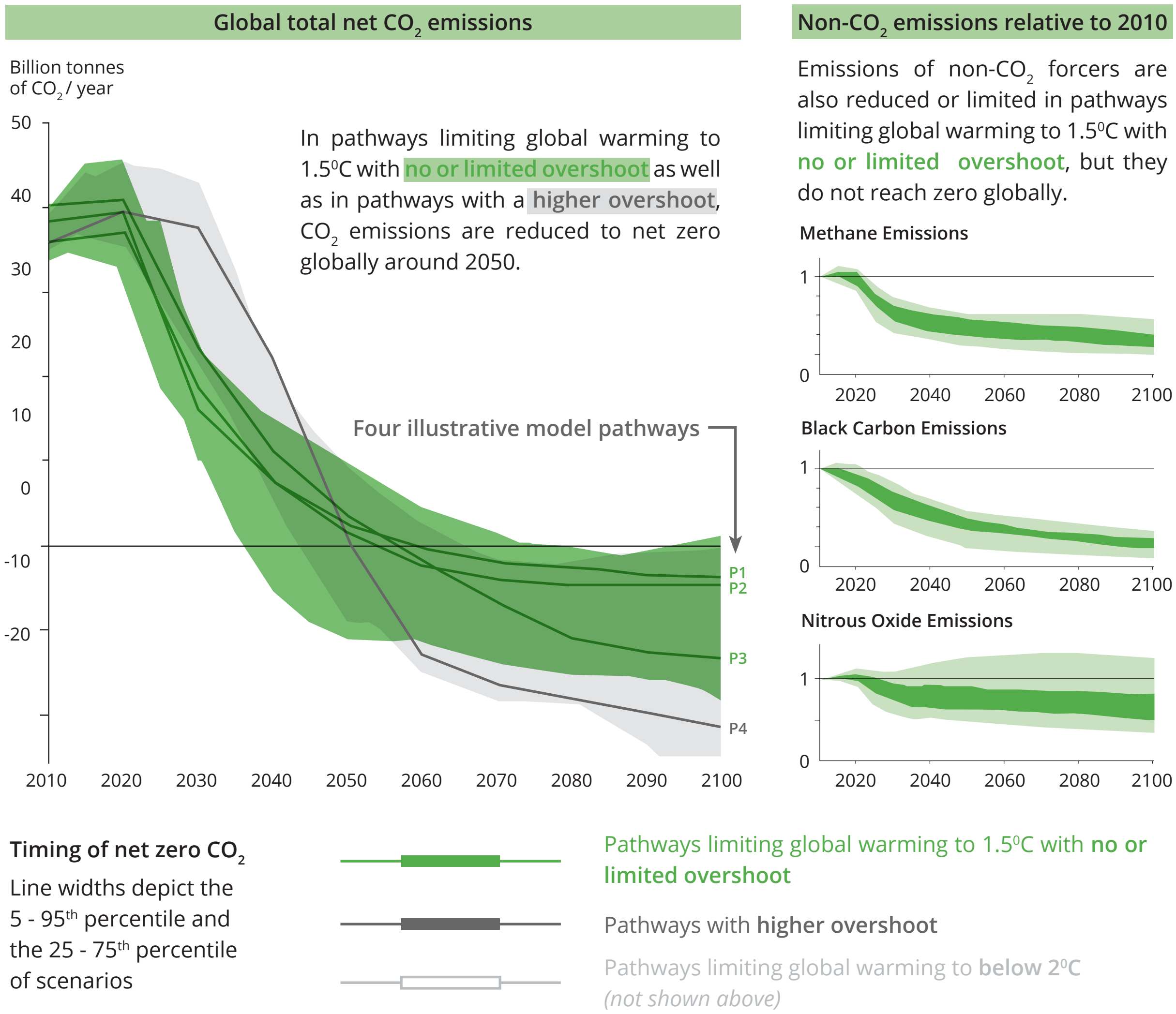
5 INTEGRITY

No double counting of emissions reductions

In the 26th UN Climate Change Conference of Parties, a new mechanism was adopted under Article 6.4 of the Paris Agreement to improve the shortcomings of Article 6.2 and Kyoto Protocol's Clean Development Mechanism. Under Article 6.2 of the Paris Agreement, countries are allowed to transfer mitigation outcomes (such as emissions reductions) for use towards nationally determined contributions or other purposes. These initiatives are country-led. Under new UN-governed mechanism, there will be a supervisory body for creating a carbon-credit database, and central accounting will be done to prevent double-counting. Both public & private sectors can participate.

To meet the goal of limiting global warming to well below 2, preferably to 1.5 degrees Celsius, compared to pre-industrial levels, countries would have to invest in decarbonizing efforts to reduce the overall GHG emissions and eventually achieve net-zero by around 2050 (refer to Exhibit-14.1).

Exhibit-14.1: Mitigation pathways compatible with 1.5°C targets



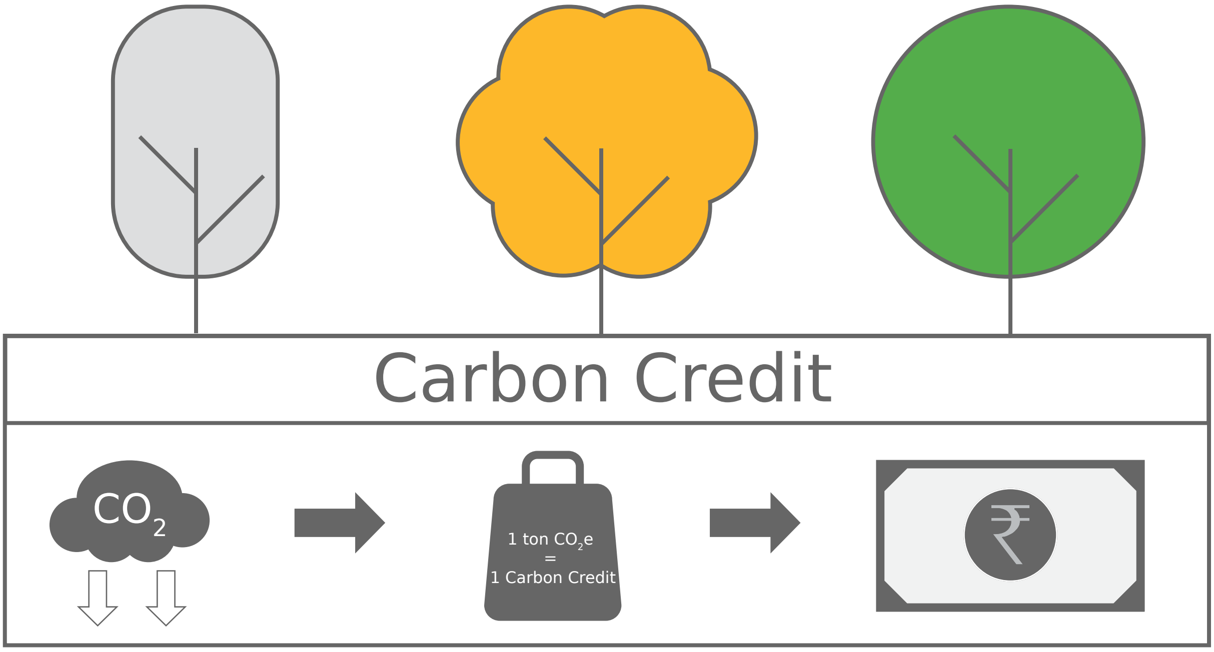
Source: IPCC[1]

India is a developing country aiming to increase its manufacturing sector's contribution to its GDP. This will increase energy demand. Therefore, India must balance the need for economic growth and the increase in energy demand with carbon emissions reduction. Sustainable economic development and a road map for reducing carbon emissions are required. Thus, India's transformation to a low-emission economy will be complex in nature compared to the developed world. It needs to map its emissions and target the funds accordingly. In this regard, various standards have been introduced worldwide. Some of these global standards are outlined in the next section.

[1] *https://www.ipcc.ch/sr15/chapter/spm/*

INTERNATIONAL STANDARDS

Exhibit-14.2: Explaining Carbon Credits



CLEAN DEVELOPMENT MECHANISM[2]

The Clean Development Mechanism was developed under the Kyoto Protocol, which was adopted in 1997. It is supervised by the Conference of the Parties (COP) of the UN Framework Convention on Climate Change (UNFCCC)[3]. Under this mechanism, industrialized countries, known as Annex I countries, are required to limit and reduce GHG emissions in accordance with the agreed targets. Annex I countries could meet part of their emissions reduction commitments by investing in projects in developing countries or by purchasing Certified Emissions Reductions, each unit equivalent to saving one metric ton of carbon emissions. Certified Emissions Reductions are issued to sustainable projects that lower carbon emissions, such as renewable energy projects or energy-efficient boilers.

JOINT IMPLEMENTATION[4]

Joint Implementation is another mechanism under the Kyoto Protocol. It allows Annex-I countries with emissions reduction targets to collaborate to earn Emissions Reduction Units from emissions reduction or emissions removal projects in other Annex-I countries. This mechanism is primarily beneficial to industrialized countries. India not being included in industrialized countries cannot benefit from it directly, but this could help fund green projects in India and develop awareness and capabilities across the value chain. India cannot claim the carbon credit under joint implementation, which could lead to double counting. India will receive the monetary benefit for mitigation projects, but the industrialized country funding the project will claim the carbon credit.

[2] https://en.wikipedia.org/wiki/Clean_Development_Mechanism#:~:text=The%20Clean%20Development%20Mechanism%20(CDM,to%20meet%20international%20emissions%20targets

[3] https://unfccc.int/kyoto_protocol

[4] https://unfccc.int/process-and-meetings/the-kyoto-protocol/mechanisms-under-the-kyoto-protocol/the-clean-development-mechanism

ARCHITECTURE FOR REDD+ TRANSACTIONS[5]

The UNFCCC Conference of the Parties (COP) created the REDD+ ("Reducing Emissions from Deforestation and forest Degradation") framework to guide activities in the forest sector that would help reduce the overall emissions from deforestation and forest degradation perspective. This also includes practices for sustainable management of forests and conservation and enhancement activities for the forest carbon stocks in developing countries. The activities that are covered under the REDD+ framework is voluntary and depend largely on the national circumstances, capacities and capabilities.

The Architecture for REDD+ Transactions is a standard that credits emissions reduction and removal from national and large subnational REDD+ programs through conservation and forest management. It also registers national and subnational project levels of forest preservation and restoration, issuing carbon credits under the TREES program.

VERRA[6]

Verra was founded in 2007, with headquarters in Washington, DC, and manages various types of programs. Under the Verified Carbon Emission program, it registers forest and wetland conservation and restoration projects, agriculture land management, transportation efficiency improvements, and many other GHG reduction & removal projects for earning carbon credits. In another framework, Verified Carbon Emission Jurisdictional and Nested REDD+, it provides guidance to national & subnational governments to support development of REDD+ programs. The Climate, Community & Biodiversity Standards is the framework created to assess land management projects. Other programs include the Sustainable Development Verified Impact Standard, the California Offset Project Registry, and the Plastic Waste Reduction Program.

GOLD STANDARD, SWITZERLAND[7]

The Gold Standard was established in 2003 by World Wildlife Fund. It is administered by a non-governmental organization based in Geneva, Switzerland. It is a standard that combines carbon emissions reduction targets with impact on the UN Sustainable Development Goals. It issues carbon credits for various types of projects that include, firstly, community service projects for waste management, water, and sanitation, hygiene projects with an impact on climate change, energy-efficient projects on efficient cooking, and mini-grid renewable energy projects; secondly, renewable energy projects such as photovoltaics, tidal, wind, and hydro energy, renewable biomass, and waste to energy; and thirdly, afforestation and reforestation projects such as planting trees. It has a Gold Standard for Clean Development Mechanisms and a Gold Standard for Voluntary Emissions Reductions.

INTERNATIONAL REC STANDARD[8]

The International REC Standard Foundation is an organization based in the Netherlands that issues Renewable Energy Certificates (RECs) for renewable energy projects. An REC is a type of Energy Attribute Certificate that represents the environmental attributes of generating one megawatt hour of energy through renewable sources. The minimum size of a project is 15 kilo-watts peak.

[5] https://www.artredd.org/about-us/

[6] https://verra.org/about-verra/who-we-are/

[7] https://www.goldstandard.org/resources/faqs

[8] https://www.irecstandard.org/about-us/#/

GLOBAL CARBON COUNCIL[9]

The Global Carbon Council is an initiative of the Gulf Organization for Research & Development. It develops standards for emissions reduction calculations and monitoring of GHG reduction projects. It issues emissions reduction units called Approved Carbon Credits for legally non-binding projects that started operations after January 1, 2016. These projects must result in the reduction of six designated GHGs, contribute to the UN Sustainable Development Goals, not harm society or the environment, and fulfill other requirements of the Project Standard[10].

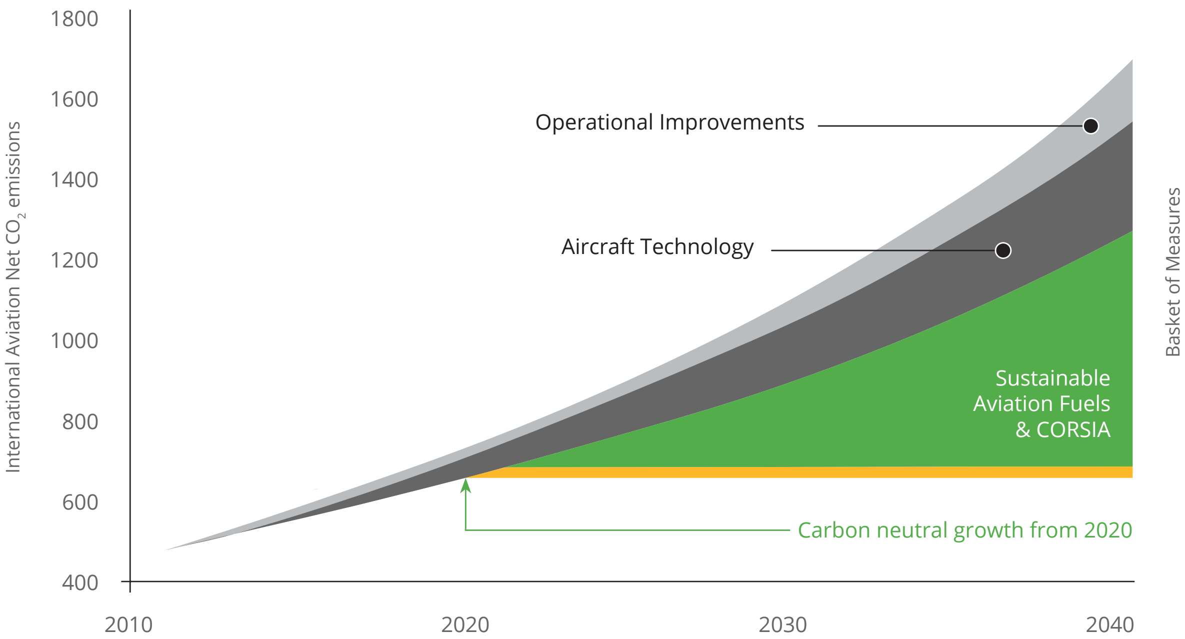
CARBON OFFSETTING AND REDUCTION SCHEME FOR INTERNATIONAL AVIATION (CORSIA)

CORSIA was launched as the first global market-based measure for the aviation sector. It is a cooperative approach to offer a harmonized way to reduce emissions from international aviation while respecting specific constraints faced by ICAO (International Civil Aviation Organization) Member States. The goal is to stabilize the levels of GHG emissions from 2020 onwards (CNG2020). This goal can be achieved by acquisition and cancellation of emissions units from the global carbon market by aero plane operators.

CORSIA enables offsetting the amount of CO_2 emissions that cannot be reduced by leveraging classical levers such as use of technological improvements, operational improvements, and sustainable aviation fuels (refer Exhibit-14.3).

CORSIA off-setting requirements will be applicable from 2027 (mandatory 2nd phase of CORSIA) for Indian Operators as per the announcements from DGCA[11].

Exhibit-14.3: Contribution of measures for reducing aviation sector emissions[12]



[9] https://www.globalcarboncouncil.com/about-gcc/global-carbon-council/

[10] http://globalcarboncouncil.com/wp-content/uploads/2021/10/Project-Standard-v3.1.pdf

[11] https://www.icao.int/environmental-protection/Documents/CorsiaBrochure_8Panels-ENG-Web.pdf

[12] https://pib.gov.in/PressReleasePage.aspx?PRID=1780858

AMERICAN CARBON REGISTRY[13]

The American Carbon Registry was founded in 1996. It operates in both voluntary and regulated global carbon markets. It issues Emissions Reduction Tons against American Carbon Registry standards, which are equivalent to the reduction or removal of one metric ton of CO_2 from the environment. It registers a wide variety of projects, including afforestation and reforestation of degraded lands, restoration of wetlands, use of certified, reclaimed hydro-fluorocarbon refrigerants and advanced refrigeration systems, landfill gas destruction and beneficial use, transportation and fleet efficiency, and carbon capture and storage.

CARBON CREDITS

In addition to the above, there are many regional and local standards. In general, five steps must be followed prior to issuance of carbon credits. After successful verification of carbon emissions reduction from a project, equivalent carbon emissions reduction units are issued.

Five steps to be taken before issuance of carbon credits

1	2	3	4	5
Project design appraisal	Validation by a third party	Registration with respective registry	Monitoring	Verification

Voluntary carbon markets (VCM) are mechanism that act as the financial intermediaries and allow carbon emitters (for e.g., a large steel manufacturer) to offset their unavoidable emissions by purchasing carbon credits emitted by projects targeted at removing or reducing GHG from the atmosphere.

As can be seen in Exhibit 14.4 above, there are different entities involved in overseeing registration, monitoring, and issuance of carbon credits for various projects. Each organization follows respective applicable guidelines to issue the appropriate carbon emissions units. It isn't straightforward for an individual company to look for and evaluate the proper organization to register, monitor, and validate its project(s). Generating awareness on multiple registry platforms with different evaluation methodologies is onerous. The presence of multiple standards and registry organizations, therefore, slows down the adoption of the carbon emissions reduction process.

India is a developing country. It has announced its target to be net zero by 2070. Taking their lead from the government, many companies have also announced plans to become net zero, and others have started planning carbon emissions reduction projects. Efforts from all industries are required in one way or another to achieve this target. Accordingly, various companies will be implementing different sorts of carbon reduction projects and looking for green financing with the support of carbon-credit mechanisms.

It is the need of the hour to have a simpler yet internationally acknowledged process to register, validate, and issue carbon credits for Indian projects with unique co-benefits and geographic attributes. India previously created its form of trading instruments, such as RECs, wherein one REC is equivalent to one megawatt hour of electricity generated from an eligible renewable energy project. RECs are now a popular instrument among the masses. Similarly, Energy Saving Certificates are issued to

[13] https://americancarbonregistry.org/how-it-works/what-we-do

Designated Consumers who have overachieved their respective Specific Energy Consumption reduction targets under the Perform, Achieve, and Trade Scheme.

It is thus necessary to have an Indian registry body that will outline an Indian standard, policy, and guidelines for the registration, monitoring, and validation of different projects under a single umbrella. At the same time, balancing the regulatory work with the execution work is necessary. Accordingly, a balancing governance mechanism is required to maintain the quality of the applicable standards and make the execution as effortless as possible. This central body can take a cue from the Petroleum and Natural Gas Regulatory Board. This governance mechanism issues various regulations, such as technical and safety standards and specifications, plus the Emergency Response and Disaster Management Plan. However, it has enlisted a group of companies who do the audits of various companies based on these regulations and submit reports to the board .

Along similar lines, the governance structure of the carbon market needs to be designed and implemented. As mentioned above, there is a need to create an Indian registry body to act as a regulatory body for the carbon market. It may enlist public or private companies to perform project report preparation, validation, monitoring, and certification. A single regulatory body and affiliated consulting companies with experts who can handle all sorts of projects will provide a suitable solution for maintaining quality and achieving the maximum adoption of carbon emissions reduction measures. This would simplify the process and help create awareness and peer learning.

Exhibit-14.4: Basics of Carbon Credits - Generation & Use

Emission Mitigation Project

i. A developer sets up a project.

ii. Developer obtains validation and registers on a certification standard

iii. Developer operates and monitors results

iv. 3rd party verifies results

Project verification & credit issuance

i. A carbon credit is "issued" i.e. a certificate is issued and a unique serial number on the registry is created for each ton of CO_2e

ii. The first credit issuance can be 2 - 3 years after the start of the project

Trading and Carbon Markets

i. Issued credits belong to project developers

ii. These can be bought & sold, and their ownership on registry charges, until a buyer "redeems" (retires), at which point the credit ceases to exist (marked as "retired" in registry)

Credits retired to meet company target

i. The carbon credits are "retired", by companies, to fulfill either voluntary emission reduction targets or to create "carbon neutral" products for their customers

CARBON PRICING

As mentioned earlier, carbon emissions also have a social cost. Carbon pricing is a method of attaching cost to GHG emissions to hold emitters responsible and to change their behavior. Carbon prices can be either be imposed by government agencies, in the form of a carbon tax, or can be market driven, in the form of an emissions trading system (ETS).

A carbon tax explicitly puts a price on carbon emissions, setting a price per metric ton of CO2 emissions in the form of a government-defined tax rate. ETS is a platform and market-driven mechanism that establishes a price on carbon emissions based on supply and demand of carbon emissions reduction units. Emitters and overachievers trade emissions units over the ETS to comply with emissions targets. ETS refers to the market in which carbon credits and certificates are bought and sold, within defined standards, for prevention or reduction of GHGs.

Results-based climate finance is a form of climate finance where funds are disbursed to the recipient upon achievement of a predefined set of climate-related results. These results are typically defined at the output or outcome level, which means that results-based climate finance can support the development of specific low-emissions technologies or the underlying climate outcomes, such as emissions reduction.

Another method is internal carbon pricing, which is a voluntary method for companies to internalize actual or expected cost of carbon under various policies and regulations. Companies adopt internal carbon prices for multiple reasons. First, the internal pricing of carbon is used for risk management purposes; as companies are increasingly exposed to regulatory and financial risks attached to the implementation of governmental carbon pricing regimes, they seek to measure, model, and manage such risks, including climate change risks. Second, internally defined prices of carbon are featured in strategic planning activities. Third, internal carbon pricing can be factored into decisions on capital investments in projects involving increases in GHG emissions, changes in energy source portfolio, and reduction in emissions via schemes such as those pertaining to energy efficiency.

Another way of implementing carbon pricing is to embed notional value in financial instruments that reduce the capital costs of low-carbon programs and projects. Explicit carbon pricing can be complemented by shadow carbon pricing, where public- and private-sector entities study how future carbon pricing or changes in carbon price will affect investment decisions. Both the United States and the United Kingdom use shadow carbon pricing for the public sector. Shadow cost pricing is a theoretical or assumed cost per metric ton of carbon emissions. With the shadow cost method, a cost of carbon is calculated within business processes, such as business case assessments, procurement procedures, or business strategy development. This price is used to demonstrate the cost of carbon implications of those business decisions. The resultant cost can then be communicated to stakeholders.

Around the world, carbon pricing has been implemented in the form of carbon taxes and ETS. Most high-income countries have implemented carbon taxes, with some of these countries now moving toward implementation of ETS. However, most middle-income countries, except for African countries, use ETS for carbon pricing. Additionally, some middle-income countries that initially implemented carbon taxes have now either implemented ETS or are actively considering implementing ETS. As a middle-income country, India should also choose ETS as its carbon pricing method[15]. Accordingly, a dedicated carbon-credit exchange trading platform is needed, the details of which are presented in Exhibit-14.3.

Some companies require less capital to achieve the same amount of emissions reduction compared to other companies. A new, advanced-technology plant may find it more economically feasible to reduce emissions over time, in contrast to an older plant that has reduced economic viability. In this case, the older plant is better off purchasing carbon credits, whereas the newer one is better

[15] https://carbonpricingdashboard.worldbank.org/map_data

off investing in carbon emissions reduction technology or carbon-capture utilization and storage. Accordingly, this arbitrage will generate a market of carbon credits. A market-based emissions trading mechanism gives industries financial incentives to reduce emissions at lower costs and provides them with an opportunity to earn profit through trading carbon emissions reduction units.

In India, trading of carbon credits was first started on the Multi Commodity Exchange of India Limited (MCX) in 2008[16]. MCX was the first exchange in Asia for the trading of carbon credits. MCX is a commodity derivative trading platform that deals in futures. An organization could sell carbon credits, either immediately or through a futures market, just like any other commodity. The futures contracts expired in December each year, at which time each trader on MCX had to close their position. The timing was matched to the European compliance markets. However, the trading of carbon credits was stopped in 2012. In India, institutional and foreign entities are prohibited from purchasing commodity derivatives under the Forward Contracts (Regulation) Act, 1952[17]. As Indian companies were not required to limit carbon emissions, they were primarily sellers of carbon credits. But without a significant buyer's market, which would typically be Annex I countries under the Kyoto Protocol, the market for carbon-credit derivatives did not flourish. The purchase of carbon credits by financial investors from around the world would have created a stream of green financing for carbon emissions reduction projects. Therefore, to create a flourishing carbon market by attracting foreign financial institutions and investors, the Forward Contracts (Regulation) Act must be amended to allow foreign investors to trade carbon-credit derivatives in India over the dedicated carbon exchange platform.

In another instance, the Indian state of Gujarat launched the world's first emissions trading system for particulate pollution in Surat. The Gujarat Pollution Control Board created the platform in collaboration with researchers from the Harvard Kennedy School, Yale University, the Energy Policy Institute at the University of Chicago, and the Abdul Latif Jameel Poverty Action Lab. Caps on particulate emissions were imposed on each industry. Emissions during the trading period were monitored in real-time using a continuous emissions monitoring system[18]. If more than 50 percent of a continuous emissions monitoring system unit's data was missing or irregular during the trading period, the unit's recorded emissions data dating back three months was used to calculate emissions. An environmental damage compensation of 200 rupees per kilogram was imposed for every kilogram of emissions above the cap at the end of the trading period. It is estimated that it resulted in a 24 percent reduction in particulate emissions[19].

Based on knowledge gained from carbon emissions trading on MCX and the Gujarat particulate emissions trading platform, a dedicated national carbon emissions trading platform needs to be designed.

The Indian government passed the Environment (Protection) Act in 1986, which has been amended several times. Section 14 of the act requires that every person responsible for an industry, operation, or process that requires consent under Section 25 of the Water (Prevention and Control of Pollution) Act, 1974 (6 of 1974) or under Section 21 of the Air (Prevention and Control of Pollution) Act, 1981 (14 of 1981), or both, or authorization under the Hazardous Wastes (Management and Handling) Rules, 1989 issued under the Environment (Protection) Act, 1986 (29 of 1986) shall submit each

[16] *News article – The Economic Times Last updated dated 09.06.2008, MCX launches futures trading in carbon credit; https://economictimes.indiatimes.com/markets/commodities/mcx-launches-futures-trading-in-carbon-credit/articleshow/3115007.cms*

[17] *Hindu business line article by Mr. Nilanjan Ghosh – Revice derivatives in carbon credit*

[18] *Harvard Kennedy School news dated: 06.06.2019 – India launches World's First Particulate Emission Trading*

[19] *IndiaSpend Explainers dated 12.11.2021 - Explained: How Surat's Emissions Trading Scheme Works To Reduce Air Pollution*

year an environmental audit report (Form V) for the financial year ending March 31 to the relevant state pollution control board on or before September 30. Accordingly, every person responsible for an industry operation or process must submit an environmental emissions report to their respective state pollution control board in the prescribed format. These reports provide an overview of yearly emissions. Continuous emissions monitoring systems should be made mandatory, as in Surat, as it will help create constant monitoring and provide a baseline for the repository of nationwide emissions, thereby reducing carbon emissions.

India is one of the few countries on track, achieving its nationally determined commitments to halt runaway global warming by achieving its emissions intensity target and performing better than other G20 peers. Banks and international financial institutions have made significant commitments toward investing in green projects and are looking for investment destinations globally. India would need a significant capital outlay (~US $ 2.5 by 2030) to meet its climate action goals; hence, it becomes crucial to improve overall infrastructure to attract foreign capital.

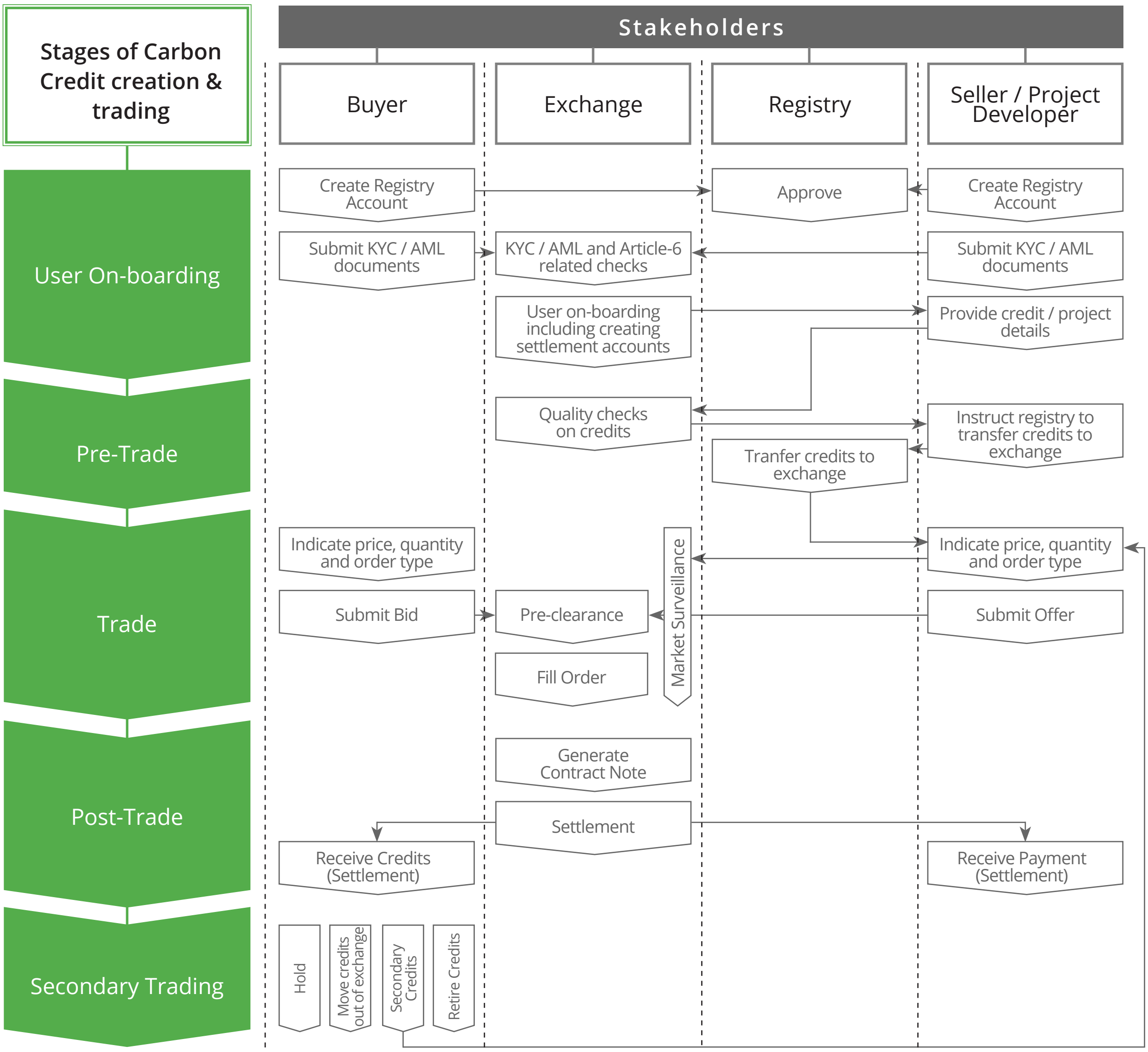
Exhibit-14.5: Role of respective stakeholders in carbon market

No.	Stakeholder and role		Considerations and activities
1	**Government** Responsible for the overall governance mechanism of the carbon market	a.	Passes acts for the formation of the Indian Registry Body and Exchange Regulator and governs regulations or amendments, such as amendments to the Forward Contracts (Regulation) Act.
		b.	What types of drivers and mandates are required to push adoption of carbon reduction technologies and measures, such as mandating the use of LED lights and green buildings?
		c.	What type of carbon pricing should be adopted (carbon tax, ETS, internal carbon pricing, or results-based carbon pricing) and what market mechanism (auctions, exchange trading, or OTC1) should be facilitated?
2	**Exchange Regulator** Regulates the carbon-credit dedicated exchange; this is a body similar to the Securities and Exchange Board of India	a.	What are the applicable regulations for marketplaces and exchanges in the target jurisdiction?
		b.	What regulations (such as those on securities trading and financial reporting) apply to the trade or purchase of spot and future contracts for carbon credits? What clarifications would help market participants?
		c.	What regulations support or hinder the development of carbon projects in nearby jurisdictions? What clarifications would help?
		d.	When will trades occur? What types of instruments (derivatives, options, swaps) should be used, and how would they be priced? What types of products and contracts would be sold on the market or exchange?
		e.	What types of participants would be part of the market?

No.	Stakeholder and role	Considerations and activities
3	**Indian Registry Body** Issues carbon-credit regulations	a. Issues carbon registry standards for different projects and decides on the type and quality of carbon credits that can be issued to the projects (standard for accounting, monitoring, and issuance of carbon credits).
		b. Who can issue carbon credits to projects? One option could be a panel of consultants who will do project registry, accounting, monitoring, and issuance of different instruments.
		c. Required to work in tandem with state pollution control boards to oversee India's carbon reduction and net-zero emissions target trajectory. What else is required to achieve the target?
		d. Where and how will the project registration, accounting data, monitoring, and instrument information will be stored? The development of a nationwide central portal or system may be required.
4	**Consultants** Conduct project registration, accounting, monitoring, and issuance of carbon credits	a. What qualifications are necessary for consultants to handle the issuance of carbon credits and instruments in compliance with relevant standards?
		b. How can transaction cost be minimized to be affordable for each individual industry player?
5	**Exchange operator** To look after day-to-day operations, such as the Indian Energy Exchange, BSE, and National Stock Exchange of India	a. Register players on the exchange (such as buyers, sellers, and brokers). What are the qualifying criteria for the exchange? How are Know Your Customer, onboarding, and quality assurance implemented?
		b. What types of order and order filling mechanisms can be enabled?
		c. How are clearing, settlement, and custody designed? How is integration with registries created and managed?
		d. What is the potential revenue model for the exchange?
6	**Buyers**	a. What might the core buyer base of an exchange be? How can this core buyer base be expanded? What are the driving incentives for buyers to purchase instruments over the exchange (such as mandatory investment in green energy by foreign investors, Indian lenders, and Indian companies)?
		b. What is the current voluntary, compliance, and speculative demand? What will the demand outlook for this buyer base be?
		c. What potential can the exchange facilitate to actualize current demand potential and scale up long-term demand?

No.	Stakeholder and role	Considerations and activities
7	Suppliers	a. How can suppliers be driven to incentivize and implement carbon emissions reduction projects?
		b. What is the catchment area for carbon projects for this exchange? How far can this catchment area be expanded? This may require implementation of continuous emissions monitoring systems.
		c. What is the current supply in this area and what is the potential supply?
		d. What are the main ways that the exchange can drive carbon project development in a supplier's catchment area?

Exhibit-14.6: End-to-end processes trading for respective stakeholders



DEVELOPMENTS IN INDIA & CONCLUSION

Against the backdrop of the Paris Agreement Rulebook being finalized in respect of Article 6, which focuses on carbon trading through bilateral/cooperative approaches and international market mechanisms, India has taken steps mandated for the Host Party/Country. India has notified the National Designated Authority for the Implementation of the Paris Agreement as well as submitted the updated NDCs to UNFCCC. In order to achieve India's NDCs, a concerted and focused approach has been adopted by various stakeholders. There have been deliberations regarding the envisaged Indian Carbon Market (ICM). Ministry of Power has been involved in the conceptualisation by engaging all concerned stakeholders. It is essential that such an envisaged ICM facilitates the achievement of India's NDCs. Perform, Achieve, and Trade (PAT) Scheme in the energy sector may be transformed into an important component of the envisaged Indian Carbon Market. There have been deliberations regarding the space for the offset market in addition to the compliance market. This may help in taking activities / projects that would help in emission / removal of GHG other than those that relate to reducing carbon emissions from the entities of the obligated sectors that form part of the compliance market.

The envisaged ICM is intended to be developed in a phased manner, that is, different actors would be brought under obligations in a phased manner gradually. This would require the development of methodologies regarding each sector/activity. The envisaged ICM may include a mix of obligated entities meeting their compliance requirements and entities participating voluntarily through projects generating offsets. It is essential to have proper documentation of the contribution of the Indian projects in meeting India's NDCs. The registry to be developed for the envisaged ICM may help in tracking all the carbon credits generated by Indian projects. Envisaged ICM would require the development of methodologies, setting sectoral targets/benchmarks and establishing the required infrastructure and governance framework.

Experiences of the PAT scheme may help the building up of the governance structure. The governance structure may have a decision-making body and an executing body. The executing framework would include the establishment/ constitution of Technical Committees, Accredited Carbon Registry and Trading Platforms, Accredited Verifiers and Validators and Carbon Emissions/ Removals Database. India is also working on developing a comprehensive national strategy for leveraging international carbon finance through Article-6 mechanisms. NDAIAPA has been mandated to take decisions in regard to the type of projects that may take part in international carbon market under Article-6 mechanisms.

Aspects crucial for an effective carbon market to function in India

1

There must be a carbon-credit standard which is simple and at the same time ensure credits of the highest quality which would recognized at international level.

2

India, given its unique position and requirements, would need to factor in global best practices and develop a unique world-class framework suited to its peculiar requirements, which can serve as a reference elsewhere in the world.

3

A simple and cost-effective supply-&-demand based mechanism needs to be created for carbon credits. This includes registration & validation of carbon credits by a third party to create a supply of credits, implementation of a continuous monitoring system for creating demand domestically and allowing foreign investors as buyers of carbon credits.

4

ETS should serve as the carbon pricing methodology of India. Accordingly, a carbon exchange needs to be formulated.

Photo Credit: Adobe Stock

Chapter

15

INSTITUTIONAL SETUP TO MANAGE ENERGY TRANSITION

In this section

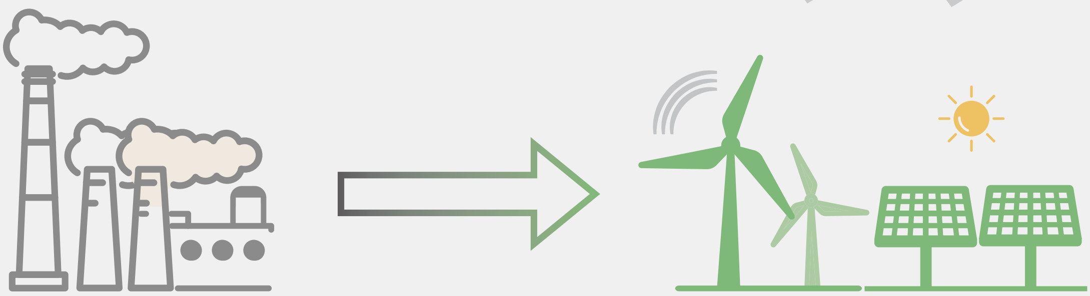
PREREQUISITES FOR AN ORDERLY ENERGY TRANSITION

Smooth and orderly energy transition will necessitate a high degree of coordination among the key protagonists in energy supply and energy consuming sectors. At the government level as well, an orderly and just transition would require coordinated moves across the concerned ministries as well as states, therefore, requiring an effective and responsive mechanism in this regard, in line with global best practices.

There are three important roles that need to be played to ensure that various efforts towards energy transition are coordinated, have the right prioritization and focus for most optimal resource allocation and regular course correction to incorporate changes in learnings, technology and other external/ internal factors. The three roles that need to be delivered and which will affect the composition and structure of the set up, are:

Exhibit-15.1: Key aspects for an orderly energy transition

There are three key roles that need to be completed for an orderly energy transition



1

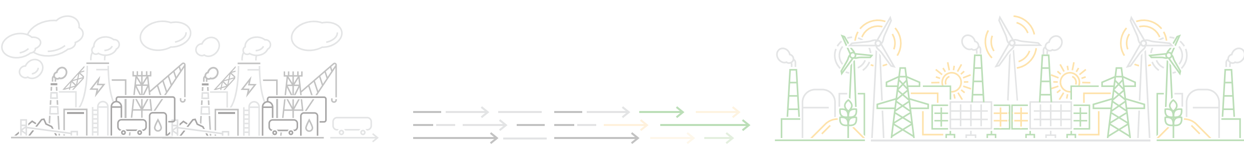
Create an integrated roadmap for an orderly transition, with actions and roles defined for different stakeholders. The task will also involve proposing policy changes, as required

2

Driving action and review basis for the roadmap and taking any course correction measures towards meeting the overall objectives

3

Providing accurate data which is the 'single source of truth' and can be used by different agencies/ people



LEARNINGS FROM ACROSS THE WORLD

Based on inputs obtained during deliberations, below is a brief description of institutional mechanisms that are currently prevalent in different countries. Countries have taken these decisions basis their pre-existing governance structure, existing agencies, and the assessed magnitude of change they must go through.

CREATING AN INTEGRATED ROADMAP TO AN ORDERLY TRANSITION, WITH STEPS DEFINED FOR DIFFERENT STAKEHOLDERS AND RECOMMENDATIONS FOR ANY POLICY CHANGES

Nations have either nominated / created a ministry or given the role of developing & driving the transition roadmap to statutory bodies.

Table-15.1: Examples of Transition Roadmaps of some countries

Country	Transition Roadmap Created
AUSTRALIA 	The Ministry for Industry, Energy and Emissions Reduction is the coordinating body that is driving integrated planning. The government has also created 'Climate Change Authority' as an independent statutory agency established to provide expert advice to the Government on climate change policy. Also, 'Technology Investment Advisory Council' provides advice on low emissions technology investment priorities, as well as economic stretch goals and pathways that will drive economic prosperity and lower emissions.

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Country	Transition Roadmap Created
NETHERLANDS 	The first plan / roadmap called NECP (National Energy and Climate Plan) was created through joint efforts of more than 100 parties, keeping deliberations broad-based to have consensus on actions. These parties signed a 'National Climate Agreement' to align on objectives, goals for different time-periods and action plan. Plan Bureau for Leefomgeving (PBL - Netherlands Environmental Assessment Agency) coordinated the effort. PBL is an independent body aimed at improving the quality of political and administrative decision-making by conducting outlook studies, analyses and evaluations in which an integrated approach is considered paramount.
NORWAY 	Ministry of climate coordinated establishment of the integrated roadmap. The plan has been created using Statistics Norway's general equilibrium model SNOW, which is a computable general equilibrium (CGE) model.
FRANCE 	The Directorate-General for Energy and Climate (DGEC), which operates under the aegis of the Ministry for Ecological and Inclusive Transition, is responsible for drafting and implementing policies on energy and energy transition. Structures within this Directorate-General include the Directorate for Energy and the Climate and Energy Efficiency Department. Directorate of Energy ensures that the energy markets (electricity, gas, oil) are functioning properly under competitive and environmentally friendly conditions and also takes into account challenges related to energy transition. The Climate and Energy Efficiency Department drafts and implements policies on energy transition and climate change. DGEC coordinated the creation of the 10 year 'Multiannual Energy Plan (MEP) and much more shorter/ medium term and granular 'National Low-Carbon Strategy (SNBC).
UNITED KINGDOM 	The Department for Business, Energy and Industrial Strategy is the nodal body responsible for creating the Climate Change Act, Carbon targets and actions related to the same.

DRIVING ACTION & REVIEW ON THE BASIS OF CREATED ROADMAP, AND TAKING ANY COURSE CORRECTION TOWARDS MEETING THE OVERALL OBJECTIVES

Most countries have given the task of review and course correction to a nominated ministry.

Table-15.2: Examples of implementation strategies adopted by some countries

Country	Implementation Strategy Adopted
NETHERLANDS 	Implementation is with relevant agencies that own their part of the agreement. The Minister of Economic Affairs and Climate Policy has a coordinating responsibility and is tasked with overall monitoring envisaged under the Climate Agreement. The Dutch government has developed a progress monitor to keep track of progress and to make any amendment in the plan (reviewed every two years).
AUSTRALIA 	The Ministry for Industry, Energy and Emissions Reduction is also the coordinating body to monitor the transition and drive any changes in plan (reviewed once every 5 years), while reporting emissions quarterly and issuing projections annually.
NORWAY 	While the responsibility of driving actions is distributed to the owning agencies, Norway has created additional institutions to drive integrated action. This includes a State-Owned Enterprise (SoE) Enova under Ministry of Climate that contributes to reduced greenhouse gas emissions and promotes technology development through providing financial support to industry, households, local and regional governments. Norway has also created another SoE Nysnø Klimainvesteringer AS (Nysnø), an investment company wholly owned by the Norwegian State, through the Ministry of Trade, Industry and Fisheries. Nysnø contributes to reducing greenhouse gas emissions through investing in non-listed companies that are working on the transition from technology development to commercialization. The ministry of climate is responsible for monitoring progress and publishing progress updates every year.

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Country		Implementation Strategy Adopted
FRANCE		The Ministry for Ecological and Inclusive Transition is responsible for preparing and implementing the government's policy in the fields of sustainable development, climate, energy transition and biodiversity. It is also the body responsible for reviewing progress on behalf of the government and taking any measures to course correct.
UNITED KINGDOM		The UK government uses the Climate Change Act to set five-yearly carbon budgets, these include the amount of greenhouse gas the UK can legally emit in a five-year period and hence is the guiding force to drive energy transition. In doing so, the government is required to consider the advice of The Climate Change Committee (CCC), which is an independent, statutory body established to advise the UK on emission targets and energy transition. CCC also reports to Parliament on progress made. There are powers under the Climate Change Act to “borrow” or “bank” amounts from one budgetary period to another. This allows the government to increase the budget by borrowing up to 1% from the succeeding period, which is consequently reduced by the amount borrowed. Conversely, if it has a surplus in a budgetary period, it can carry all or some of it forward to the next period.

PROVIDING ACCURATE DATA WHICH IS THE ‘SINGLE SOURCE OF TRUTH’ AND CAN BE USED BY DIFFERENT AGENCIES / PEOPLE

Most countries have their own statistical agency / agencies responsible for consolidation of data related to energy transition and emissions reporting. Usually, these are not policy agencies, but just purely statistics compiling agencies. Some countries have also nominated distributed agencies to be the owners of data in their domain.

Table-15.3: Examples of how countries have developed platforms for reporting of accurate data

Country		Climate Data Reporting Platform
NETHERLANDS		Nominated ‘National Data Administrators’ across different agencies coordinate their data relating to the energy transition, provide access to that data in a user-friendly manner and collectively collaborate on correcting any shortcomings in the supply of data.
NORWAY		Statistics Norway is the central body that coordinates collection, validation, and publishing data from various sources.
UNITED KINGDOM		While different agencies collect data, Office for National Statistics is the coordinating body on publishing the same.

PROPOSED SETUP FOR INDIA

CONSIDERATIONS FOR DEVELOPING INDIA SPECIFIC INSTITUTIONAL MECHANISM

1 **Clear accountability for action steps**

The mechanism should ensure that the accountability for various steps is clear

2 **Avoid creation of new institutional bodies**

To the extent possible, use the pre-existing performing institutional bodies, as much as possible, given the need to move with speed. Use whatever has worked well so far, revitalize that needs some nudge / change so that the entire structure has capacity to deliver as a cohesive unified, larger framework.

3 **Broad based alignment**

The mechanism should ensure that there is alignment amongst various stakeholders on action plan so that they take real ownership of their part

4 **Timely decisions on any changes / course correction**

The governance mechanism should ensure that the right people in the administration are engaged at the right frequency in process of taking view on any course correction/ changes

MINISTRY LEVEL SETUP

Given that the energy transition touches the energy providers as well as energy consumers, the core structure may be created around energy providing Ministries consisting of MOPNG, MNRE, Ministry of power and Coal Ministry at the core. NITI Aayog and MOEFCC may be permanent invitees. The process may be coordinated by MNRE. Other ministries may be involved from time to time, as needed. This set-up should orchestrate creation of the roadmap and help it get adopted along with the stakeholders. The roadmap may have the owners for different actions with responsibility for the timelines to meet commitments as a nation.

A group of Ministers may be set up consisting of Ministers from the four energy related Ministries. A larger Committee of Secretaries under Cabinet Secretary may also be set up by including large energy consuming Ministries like MORTH, Steel, Cement etc. The Committee can also get inputs from Domain experts as and when required.

PROVIDING ACCURATE DATA WHICH IS THE ‘SINGLE SOURCE OF TRUTH’

There are already agencies that are entrusted with the task of collecting and reporting data across different ministries/ sectors and are considered the authority on data pertaining to their sectors (besides ownership of the relevant ministry). Notable amongst these are Petroleum Planning and Analysis Cell (PPAC) for PNG and Central Electricity Authority (CEA) for power. Similar agencies to be authority on data related to their respective sectors may be set-up in coal, RE and other ministries. Bureau of Energy Efficiency (BEE) may be entrusted the task of validating and consolidating all data related to energy transition and publish the same in a structured manner. Given that India will be largest source of incremental energy demand over the next few decades, it is high time that this set up develops strength to issue own India Energy Outlook which should graduate to being used as reference by all other agencies. This data would provide the 'single source of truth' on the topic relating to energy and energy transition across different stakeholders.

This broad template / structure would ensure using existing agencies to collect and report data (who have played their role effectively so far in their respective domains and are best placed to figure out need for refinements, and also ensuring ownership of the data remains with the natural owners).

MODELLING & PROJECTIONS

NITI Aayog already has the capability and capacity to conduct modelling exercise and make projections for future. Modelling inputs are essential for projections, future planning, course correction and for related decision making process. NITI Aayog also has the capacity for data processing and providing expert support to the ministry level set-up on suggested actions as well any strategic course correction needed in the roadmap basis any important changes in the market, technology and other indicators.

EXPERT GROUP ON ENERGY TRANSITION

An expert group comprising of industry representatives from different sectors, both energy demand and supply may be created to provide inputs to both the ministry level set-up and NITI Aayog. The expert group might meet at a regular cadence (e.g., once in a quarter) to discuss various advancements in different sectors and create white papers on various topics for the consideration of various stakeholders. People from industry, academia associated with this sector and resources from relevant think-tanks might also be included in this expert group.

TIE-UP / LIAISON WITH INTERNATIONAL ORGANIZATIONS

There needs to be a mechanism to constantly scan and note the relevant developments taking place globally, to get a quick idea of what might work and what needs to be avoided. There are several international organizations that are leading the thinking on energy transition areas, especially on technology. Various companies in the India energy space may also partner with them, given India energy transition would provide immense business opportunity as well. Given that a lot of these Indian companies working the energy and related domains are State Owned, the government may ease out norms/ encourage international partnerships and joint ventures to accelerate the process.

Overall, this institutional mechanism will ensure that the existing institutional framework of creating the plan, actions steps and reviews as well as data will largely continue given the natural ownership that has been built over the years. As a part of the exercise, the current status of activities of the involved agencies needs to be appraised to assess any gaps and the interface issues if any be plugged, so that the coordination with different ministries and energy companies, which is critical, can be streamlined. This mechanism will also ensure that the latest thinking from various quarters (e.g., industry, academia and international agencies) is incorporated in the plan as well as used for any course correction. a focused approach to issues at hand with mechanism for building in the international learning about what works and what needs to be avoided / done differently to make it work, will help India transition with minimum regretted moves. Such mechanism with also ensure that the accountability remains clear and each protagonist understands and delivers on its role and responsibility while ensuring coordinated action.

Chapter 16

SUMMARY OF RECOMMENDATIONS

In this section

EPILOGUE

Events over the last two years have brought the issue of energy security to the forefront all over the World. The monopoly of some countries over the production of energy, particularly oil and gas, and the dependence of other nations on imports to meet even the basic energy requirements should not have been much of a concern in a free, connected and transparent world market for energy when the demand and supply are balanced through the interplay of market forces. However, a slight reduction in supply or disruption in the supply chain can push the price of commodities like oil and gas with inelastic demand to unimaginable levels creating a financial crisis for nations, business entities and individuals, as witnessed during the ongoing energy crisis. Price build-up during the recent past was never anticipated, though the energy prices are now trending lower. Therefore, energy security at an affordable price has become the most important issue for all, especially energy-importing countries. This has also resulted in thoughts around the fast-tracking shift to clean energy sources. The high energy cost has also brought focus on the viability of new energy resources like Hydrogen and its derivatives. When the entire world concentrates on any particular sector or starts working on a pathway, one can expect major developments and results. Therefore, we may expect a reduction in the cost of storage, a reduction in the price of Hydrogen and some more innovative technologies in harnessing renewable energy. To overcome the issue of import dependence, harnessing the full potential of all domestic energy sources, including bio-based sources, needs to remain in focus.

The oil and gas sector will play an important role in the transition of global energy systems, and in fulfilling the ambitions of net zero. The sectors' understanding of energy systems, stakeholder expectations, low carbon innovation and investment making ability would be key to unlocking the doors of a greener, cleaner future.

CHAPTER-WISE RECOMMENDATIONS

In this section, all the key conclusions, learnings and recommendations are summarized at a chapter-level. These constitute all of the committee's recommendations from the study that has been carried out and detailed in this report.

1 GLOBAL ENERGY TRANSITION

To meet the 1.5°C target as envisioned in the Paris Agreement, it is important to reduce GHG emissions in the next eight years by around 50 percent in addition to expanding renewable energy, decarbonizing the transport & industrial sectors, rapidly phasing out coal and investing in carbon removal.

2 INDIAN ENERGY TRANSITION

Industrial and power sectors account for most of India's emissions of 2.7 GtCO2e. Decarbonizing these sectors and shifting to renewable power generation, electrification of heating in industries, clean fuels, better energy efficiency, and circularity in plastics will be the way forward.

Societal & Economic changes needed to support decarbonisation

- Catalyzing effective capital reallocation and new financing structures
- Scaling-up climate finance which could come from both traditional and specialized financial instruments (e.g., Green Bonds)
- Cultivating voluntary carbon markets, which would include markets for avoidance/removal and compliance credits
- Providing demand signals & incentives to lift demand can help create a vibrant market.
- India must look for technologies to use coal with lower carbon footprint in the medium term, for which R&D efforts need to continue.
- Currently, only about 18% of India's energy needs are met through power flowing from the grid. This must increase to ~40% by 2035. Wider use of electricity will translate into a shift towards greater use in transport, cooking and industrial applications.
- The generators have long-term PPAs with Discoms, which are specific to their thermal power stations. If these generators are allowed to generate extra power using renewable resources and supply along with the coal-based power, they would have some spare thermal capacity which can be used for grid balancing and to cater to an increase in demand over the years without having to add more power capacity.
- Gas is expected to play a critical role in Indian energy transition due to lower carbon footprint, and to resolve concerns on intermittency of RE. To use expensive power

like gas-based power for grid balancing, a fund should be created at national level. The expensive power-supplying stations should have a defined tariff based on expected PLF if they operate only for grid balancing.

- Buildings are another category consuming a considerable quantity of energy. Energy-efficient building designs with provision for rooftop solar have to be mandatorily enforced. There is a requirement for an updated national-level rating system that should include renewable energy usage. There is also a requirement for many rating agencies and rating domain professionals to cover the entire country with an updated ECBC mechanism administered by Bureau of Energy Efficiency.
- To provide stability to the grid considering the intermittent nature of the renewable energy sources, the option of using stationary battery energy storage with AI-based management to sync with the grid and feed stabilizing power can be considered.
- Enable re-skilling & re-deployment of workers to ensure the right skills while also instituting support programs (including insurance)
- Building a global leadership position to lead dialogue on just & equitable transition regime
- India may take a leadership position by creating International Biofuel Alliance to increase location-specific options, which can enable countries to pursue journeys that suit their specific circumstances.
- For grid transition from largely coal-based to renewable power (utilizing 500 GW RE power by 2030), it's important to maintain a healthy ratio of Wind, Solar and Hydro.
- Supporting frameworks for promoting RE based on favourable local characteristics need to be built up. Solar power is viable in most parts of the country, while wind energy remains restricted to only some coastal states & Rajasthan. Prospects for offshore wind energy need to be fully harnessed. The eastern part of India can get hydro from North-East. The northern part of the country can get hydro from J&K, Himachal and Uttarakhand, and some hydro can also flow from Nepal. This will require state-wise planning, with each state having its RPO obligations, including for storage-based electricity drawl.
- As storage cost of electricity remains high, large-scale grid storage may not be possible. Therefore, to manage the grid, National Load Dispatch Centre has to play a more active role. A thorough study of load curve in various parts of India & variation over the year would reveal that some states can support each other. E.g. power requirement in Punjab & Haryana during paddy sowing season is very high, whereas a similar high peak in Madhya Pradesh is at a different time. In south India, the peak months are different. Therefore, each State tying up from separate dedicated power stations would imply non-utilization of the resources optimally. So, all these major seasonal variations should be taken care of at the national level. Therefore, the creation of a national pool controlled by the National Load Dispatch Centre should be actively pursued.
- Industry, a large energy consumer, is already shifting to electricity or natural gas. However, some hard-to-abate sectors like Steel and Cement still use a large quantity of coal due to their peculiar requirement. Industries shifting to electricity wherever possible has to be ensured in the next three years. Natural gas can be the transition fuel for next 15-20 years. There should be closer coordination with the industry, with larger ones of them committing to transition within a given timeframe.
- India has abundance of coal and it may not be possible to discontinue coal totally for the next 15 to 20 years. Cleaner pathways of coal usage have to be invented and encouraged. Gasification of coal is advantageous in this regard as carbon capture becomes easier in this case and several derivatives like methanol can be used as transition fuels. There are also other technologies under development which can be deployed to convert coal into energy with minimal emissions. R&D in these areas needs to be supported and encouraged.

3 ENERGY TRANSITION OIL & GAS PSUs

Scope 1 & 2 emission reductions may be targeted by oil sector companies by 2040. Scope 3 emissions need to be measured accurately. Still, their reduction would work in conjunction with broader energy production, and usage shifts would need to be planned in the context of India's overall energy transition. Carbon footprint measurement and abatement plans must become a component of performance reviews over time. Other sectors should also work on carbon footprint measurement and abatement within similar timeframes.

Key recommendations to improve energy transition in O&G companies:

- Formalize internal organization set-up to tackle energy transition by establishing a standardized structure for a cross-functional group dealing with the entire gamut of issues relating to ESG
- The initial focus to be on energy efficiency, with a target to figure in the top quartile of the Solomon index.
- Adoption of alternate fuels by expediting the shift to green hydrogen & natural gas

4 BIOFUEL OPPORTUNITY IN INDIA

Key policy recommendations for the bio-ethanol sector

- Supply related
  - » Biomass management is a separate area of work which should be handled by Ministry of Agriculture. Out of roughly 5,000 MMT per year of agri-residue, at least 1,000 MMT should be targeted to be collected and marketed for various uses like CBG, Palletization, use of power plants and the industry.
  - » Till main petroleum-based fuel products are not part of the GST regime, a mechanism / accounting framework to help abate the impact of stranded credit / dual taxation for entire Biofuels, like ethanol and CBG needs to be established, even if the same are flowing and sold in mixed mode with fossil fuels.
  - » Promote technology to produce ethanol from nonfood feedstock incl. 2G and 3G to minimize trade-offs with food production

» As the biofuels like Ethanol and CBG may require usage of existing network for transportation being used for transportation of fossil fuels, system of separate accounting, as above, should enable the person supplying these products at one place to receive delivery of the same at another place as only biofuel (CBG or Ethanol).

» Encourage cultivation of maize, sweet sorghum etc in short to medium term to ensure the efficient, environment-friendly and expedited transition. Corn variants with higher starch content should be promoted.

- Vehicle standards / awareness

  » Utilize recognized certification systems (e.g., ISCC) for sustainability and GHG savings through the use of biomass, and work towards institutionalizing the same.

  » Institutionalize an accounting body for fuel which provides certificates to entities / individuals based on green-fuel consumption

  » Incentive structure for mobility to factor in the net carbon footprint of different pathways.

  » Support system, both financial and policy-based, for farmers and value chain entrepreneurs to help establish fully functional bio-based businesses.

- Associated Infrastructure

  » Infrastructure for handling ethanol should be developed with public storage systems like railways, distilleries, OMC depots & rake loading.

Key policy recommendations for bio-diesel sector

- Promote research on new feedstocks to ensure steady supply: Since the currently identified feedstock is insufficient, an R&D focus for building international alliances to explore new feedstock (e.g., biomass, algae) that are abundant in India is critical.

Key policy recommendations for CBG sector

- Promote high-yield feedstock such as crop residue & agri-waste through targeted policies.
- Route urban waste to CBG plants to ensure generation at scale.
- Provision for book & claim or providing a trade mechanism for carbon trading in CBG Plants.
- Provision of multiple injection points by city gas distribution companies to promote direct selling.
- Agri-waste, bio-based solutions should provide for exclusivity to ensure the sustained availability of feedstock over the project life.
- CBG needs to be promoted in a big way. 10% blending of the CBG in Natural Gas should be targeted by 2030. CBG transportation through pipelines laid for natural gas should be allowed free of cost for 10 years as an incentive for the sector. The flow should be treated as not blended with natural gas if it is marketed separately. For this, a method of accounting needs to be established.
- Biogas driven tractors and other farm equipment has to be introduced to build-up utilization of biogas

5 CLEANER COOKING FUELS FOR INDIA

- Blending alternatives in LPG need to be researched (e.g., DME blending in LPG).
- LPG must be blended with compressed biogas made from urban waste and other sources available around these cities. The blending percentage can gradually increase. Hydrogen blending up to 3% by volume is possible, which needs to be introduced as the hydrogen ecosystem builds up.
- In cities, the transition could be towards electricity & PNG. In contrast, in rural areas, blends of LPG & DME along with solar solutions may be explored to reduce the carbon footprint effectively.
- Use of Methanol and Ethanol as cooking fuel should also be popularized by introducing user-friendly products.
- Electric / solar cooking needs to be promoted through campaigns. The target should be to have 25% of households using electricity for cooking by 2030.
- Target: 5 cr PNG connections in next five years.

6 PURSUING HYDROGEN

- Incentivize green hydrogen usage for all new / upcoming facilities through policies
- Green hydrogen by bulk users like refineries, fertilizer and hard-to-abate sectors could be the focus area.
- Popularize green hydrogen derivatives for ships, such as ammonia and methanol, while simultaneously developing ports for bunkering
- Export of hydrogen derivatives to encouraged.
- Direct usage of hydrogen in industrial applications may be undertaken.
- Efforts must be made to study and explore increasing Hydrogen %age in Natural Gas in energy applications wherever NG is being / capable of being used as a transition fuel.
- For HCNG-based transport, guidelines can be further elaborated. CBG conversion to hydrogen should be acknowledged as a green transportation / green H_2 option.

7 ENERGY FOR SURFACE TRANSPORT

- **2-Wheelers and 3-wheelers**
  - » Standardization of EV two wheeler is required to ensure build-up of charging and promote battery swapping.
  - » EVs may be promoted as the optimal solution in preparing for phasing out internal combustion engine two / three wheel vehicles by 2035. In the intermediate period, policy support for ethanol-blended fuel with an increasing blend ratio needs to be given.

- **4-wheelers**
  - » Four-wheelers, including passenger cars and taxis, to partially shift to electric and partially to ethanol blended Petrol with almost 50% share in each category.
  - » Along with 40% ethanol vehicles, required changes in engine modifications and revision of emissions standards also need to be addressed.
  - » Diesel-driven 4-wheelers may be eliminated as soon as possible. Therefore, a ban on diesel-powered four-wheelers in all Million Plus cities and all towns with high pollution has to be enforced in five years, i.e. by 2027.
  - » Long-term focus on transitioning to EVs with CNG as transition fuel (upto 10 -15 years)
  - » Vehicles with flex-fuel capabilities and hybrids may be promoted in the short & medium terms. This can be done through application of fiscal tools like taxation.

- **City Buses**
  - » No diesel city buses addition be allowed in urban areas, to drive towards transition towards clean fuel urban public transport in about 10 years.
  - » Expedite all-electric bus adoption with measures such as Govt. purchases.

- **Intercity Buses:**
  - » Shift towards all-electric buses with CNG / LNG as transition fuels, where CBG also needs to serve as a supplement
  - » Long-term focus should be on shifting to railways and other mass-transit modes.

- **Ecosystem for EV promotion**
  - » The overall direction for surface transport has to be towards transitioning in favour of EVs. Requisite support for creating an ecosystem for EV-based mobility has to be promoted through a policy and financial support system.

- **Cargo**
  - Railway share of cargo, presently at ~23%, may be targeted to increase above 50%.
  - Commercial vehicles may transition to LNG in the short term.
  - From 2024 onwards, all new registrations for city delivery vehicles should be only electric so that in the next 10 years, 75% of the city delivery vehicles can be electric in all the Million+ cities and other specific cities identified by the MoEF&CC.
  - Other transition fuels could include ethanol and methanol blends

8 ZERO CARBON SHIPPING

- Promote ammonia & methanol as alternate fuels
- Develop port hubs for bunkering ammonia

9 SUSTAINABLE AVIATION FUEL (SAF)

- Promote widespread adoption of SAF, with the HEFA & ATJ route being the most cost-competitive pathway to enable the same
- Ethanol blending in the short & medium term may also be explored
- Relevant entities and scientific institutions may focus on R&D of new indigenous feedstocks & processing technologies for the efficiency enhancement of SAF value chain

10 TRANSITION FUEL - NATURAL GAS

The oil and gas sector will continue to play an essential role in the transition of global energy systems and in fulfilling the ambitions of net zero. The sectors' understanding of energy systems, stakeholder expectations, low carbon innovation and investment-making ability would be key to unlocking the doors of a greener, cleaner future. This also allows the domain entities to capitalize on adjacencies to provide solidity to their business models.

- Promoting LNG-based transport in the LCV & HCV segment. LNG is a promising alternative fuel with lower emissions and higher calorific values than diesel.
- Strengthen the Gas Exchange for a faster transition towards natural gas; this also provides an opportunity for the country to develop its own index.

11 DIESEL - FUTURE POSSIBILITIES & BLENDING

- Increased blending may be mandated to ensure a higher proportion of green fuels in the energy mix and diesel replacement in the long run.
- Research on appropriate additives and technology development for the same may be perfected in the short term to improve efficiency.

12 ROLE OF TECHNOLOGY AND INNOVATION

- Deploy advanced digital tools for energy efficiency, emission tracking and mitigation: Deployment of digital technologies can create an ecosystem focused on emission monitoring and reduction.
- Establish coordination framework knowledge sharing and joint accountability: Set up sectoral bodies to reap the benefits of efforts being made by individual entities
- India needs to promote a coordinated institutional framework for R&D efforts in energy transition-related areas, leveraging all domestic R&D institutions to ensure the quickest transfer of successful technologies/ ideas from the lab to the field.
- Concerted efforts to establish and support an R&D infrastructure for bio-based energy.

13 GREEN FINANCE

- Pursue higher green financing flows to India through a specialized body under the administrative set-up created to handle energy transition.
- To arrive at a healthy mix of international and domestic carbon markets, the high-cost RE sources should be kept separate from the international carbon markets and may not count within NDCs.
- Establishing a legally enforceable price on carbon.
- Define an internationally aligned green taxonomy and disclosure framework.

14 CARBON MARKET & CARBON PRICING

- Standardization of carbon credits to ensure that registered credits are of the highest quality and tradable at the international level.
- A simple & cost-effective supply-and-demand process for carbon credits needs to be created.
- India must also utilize the provisions of clause 6.2 of the Paris Convention to have arrangements with some other countries that on their own, do not have good RE potential.
- ETS may serve to enable the carbon pricing methodology for India; correspondingly, a carbon exchange needs to be established and supported.
- India should keep Offshore wind, green hydrogen, solar thermal, CBG, ethanol (1 G and 2G), SAF, carbon capture, tidal wave energy, and other technologies for harnessing ocean energy etc., outside NDCs.

15 ADMINISTRATIVE SETUP

- The Administrative Set-up may be created around energy-providing Ministries consisting of MOPNG, MNRE, Ministry of power and Coal Ministry at the core. NITI Aayog and MOEFCC may be permanent invitees. The process may be coordinated by MNRE.
- A Group of Ministers may consist of Ministers from energy-related Ministries. A larger Committee of Secretaries under the Cabinet Secretary may also be set up by including large energy consuming Ministries like MORTH, Steel, Cement etc. The Committee can also get inputs from Domain experts as and when required.
- For collecting and reporting data and its ownership across different ministries/sectors, existing bodies like Petroleum Planning and Analysis Cell (PPAC) for PNG and Central Electricity Authority (CEA) for power etc., should continue to play their role. The Bureau of Energy Efficiency (BEE) may be tasked with validating and consolidating all data related to energy transition and publishing the same in a structured manner.
- NITI Aayog may continue to provide modelling expertise and make projections for the future, which are essential for planning, monitoring, course correction etc., and as input for the related decision-making process.
- An expert group comprising of industry representatives from different sectors, both energy demand and supply, may be created to provide inputs to this set-up.
- There needs to be a mechanism to constantly scan and note the relevant developments taking place globally to get a quick idea of what might work and what needs to be avoided.
- Upgraded institutional mechanism across the energy domain should, besides being a repository and provider of data, also act as the lead agency in issuing world-class India Energy and Energy Transition Outlook for global reference.

Transition is much more than a one-time event. It is like a journey that takes time, preparation, and planning to bear fruits.