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Fueling the Future

A Comprehensive Report on Biofuels & Green Hydrogen

October, 2023

Foreword

With the growing impact on the environment due to the ever-increasing greenhouse gas (GHG) emissions resulting from the exploitation of natural resources, it is paramount to take proactive steps to limit the Earth's warming to 1.5°C & look for more sustainable & environmentally friendly solution.

India, with its burgeoning population and expanding economy, is faced with the dual challenges of meeting the energy demands of a growing nation while striving to preserve the environment for future generations & achieve its target to become carbon zero by 2070. Transportation is one sector which contributes significantly to the India's GHG emission. Thus, identifying alternatives to fossil fuels is becoming important day by day. In this context, green fuels, including hydrogen and biofuels derived from organic materials such as crops, agricultural residues, and waste, emerge as promising alternatives. The adoption of green fuels not only helps the environment but reduces the burden on India's energy import bill, enhances energy security, create employment & provides an additional source of income for farmers.

The Indian government has been actively promoting the adoption of biofuels & laid out a clear framework in its National Biofuels Policy, 2018. The well-defined roadmap and financial support provided by the government have enabled India to achieve its E10 target in 2022 ahead of schedule and accelerate the timeframe for the adoption of E20 to 2025.

The success of the E10 target underscores the government's strong focus on biofuels. This certainty is bound to attract investment and create business opportunities across the green fuel value chain, ranging from technology development to final consumption.

We are excited to see how the green fuels ecosystem evolves and helps India achieving its net zero target & in the process become self reliant. This report reflects our perspectives as of 23rd October 2023.

We would like to thank the Hon'ble Prime Minister and the Hon'ble Minister of Petroleum & Natural Gas for their vision which has inspired us to create this report. We would also like to thank Chamber of Commerce & Industry of India (CCI) for their efforts and support which has contributed to the perspectives presented here.

We, at Praxis Global Alliance, look forward to continuing this discussion and exchanging notes with various industry participants that are fueling the growth of this sector.

Munindra Kumar
Director General,
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Glossary of terms

Acronyms	Description
AIF	Agri Infrastructure Fund
ALK	Alkaline Water
BDBP	Biodiesel Blending Programme
BOP	Bill of Payments
CAGR	Compounded Annual Growth Rate
CBG	Compressed Biogas
CFA	Central Financial Assistance
CNG	Compressed Natural Gas
CSIR	Council of Scientific and Industrial Research
CSR	Corporate Social Responsibility
CY	Current Year
E10	10% Ethanol in a Blended Petrol Fuel
EBP	Ethanol Blending Program
ESY	Ethanol Supply Year
EUR	Euro
EV	Electric Vehicle
FCEV	Fuel Cell Electric Vehicle
FDI	Foreign Direct Investment
FOM	Fermented Organic Manure
FY	Financial Year
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GOI	Government of India

Acronyms	Description
GST	Goods and Service Tax
GT	Giga Tons
iCAT	International Centre for Automotive Technology
IRA	Introduce Inflation Reduction Act
LPG	Liquid Petroleum Gas
MSP	Minimum Support Price
MSW	Municipal Solid Waste
MT	Metric Tonne
NBDB	National Biofuels Development Board
NBM	National Biofuel Mission
NHM	National Hydrogen Mission
OEM	Original Equipment Manufacturer
OMC	Oil Marketing Company
OPEC	Organization of the Petroleum Exporting Countries
PEM	Polymer Electrolyte Membrane
PM	Particulate Matter
PPM	Part Per Million
RFS	Renewable Fuel Standard
TAT	Turnaround Time
tCO_2e	Tonnes of Carbon Dioxide Equivalent
TBO	Tree Borne Oilseed
TPD	Tonnes Per Day
UCO	Use Cooking Oil

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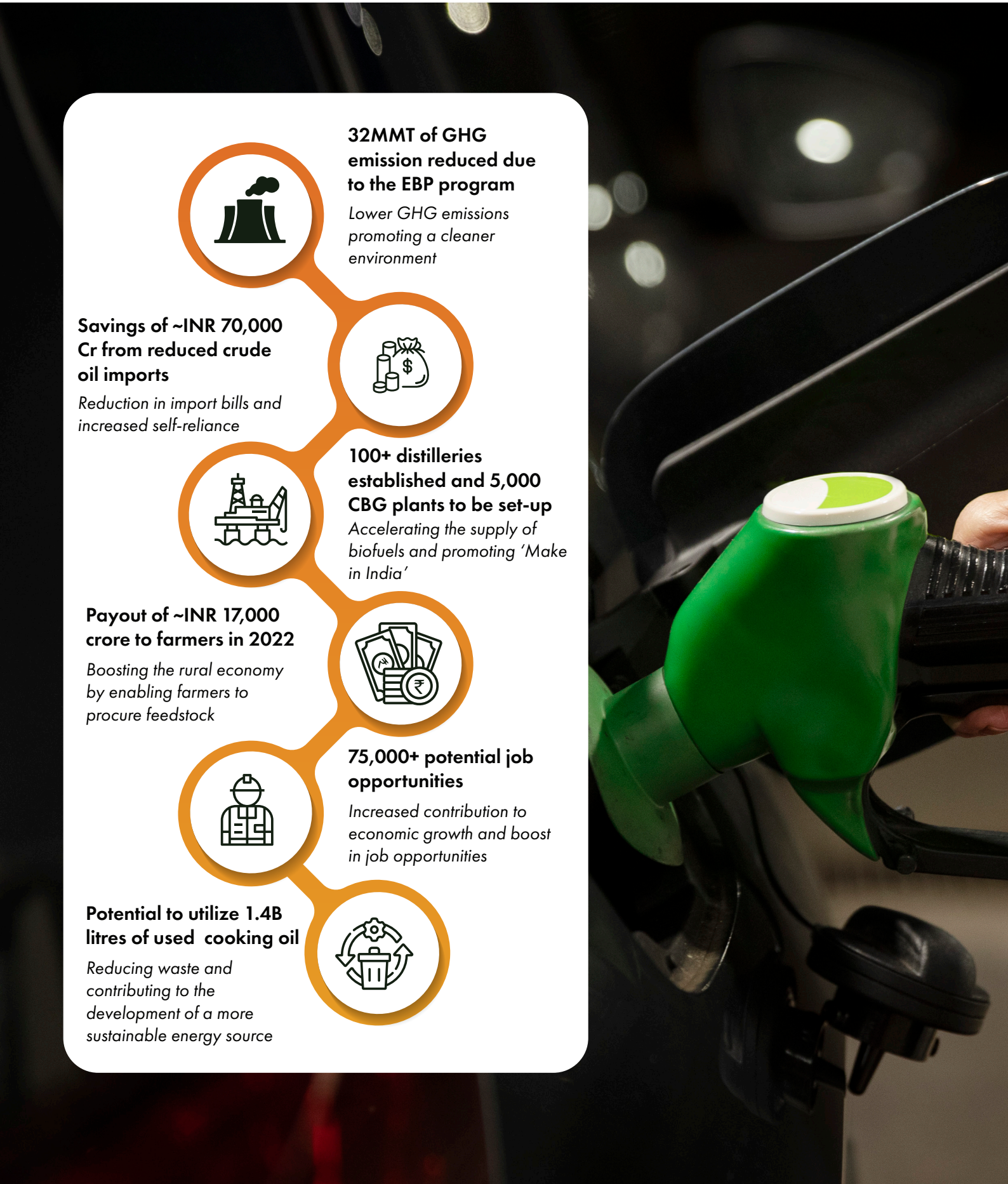
Key Highlights



32MMT of GHG emission reduced due to the EBP program

Lower GHG emissions promoting a cleaner environment

Savings of ~INR 70,000 Cr from reduced crude oil imports

Reduction in import bills and increased self-reliance

100+ distilleries established and 5,000 CBG plants to be set-up

Accelerating the supply of biofuels and promoting 'Make in India'

Payout of ~INR 17,000 crore to farmers in 2022

Boosting the rural economy by enabling farmers to procure feedstock

75,000+ potential job opportunities

Increased contribution to economic growth and boost in job opportunities

Potential to utilize 1.4B litres of used cooking oil

Reducing waste and contributing to the development of a more sustainable energy source

01 Introduction

Global warming, a consequence of human activities, has unleashed an unprecedented wave of environmental, social, and economic challenges that, if left unaddressed, will reverberate for generations to come. Over just 170 years, human actions have propelled a staggering 48% increase in CO_2 concentrations, a rate that eclipses what nature would have taken 20,000 years to achieve.

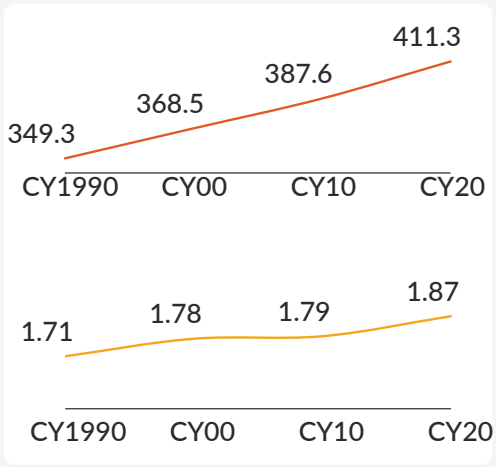
Unrestrained human activities have propelled the concentrations of greenhouse gases (GHGs), particularly carbon dioxide and methane, to concerning levels, as illustrated in Exhibit 1.1. Furthermore, the Earth's average global temperature has surged by just over 1 degree Celsius since 1880, a critical shift with the potential to unleash unprecedented and disruptive events because of climate change.

The alarming statistics continue to mount, with sea levels rising at twice the rate seen in the previous century, resulting in an approximately 8-inch increase over the last hundred years. More than 11,000 weather, climate, or water-related disasters have wreaked havoc over the last five decades, claiming countless lives. In addition, climate change is pushing over 10,000 species towards the brink of extinction. The human cost is also staggering. Over the past decade, more than 23 million people found themselves displaced each year due to weather-related events. The implications of unchecked climate change are grave, with projections suggesting an annual death toll of 3.4 million by the close of this century.

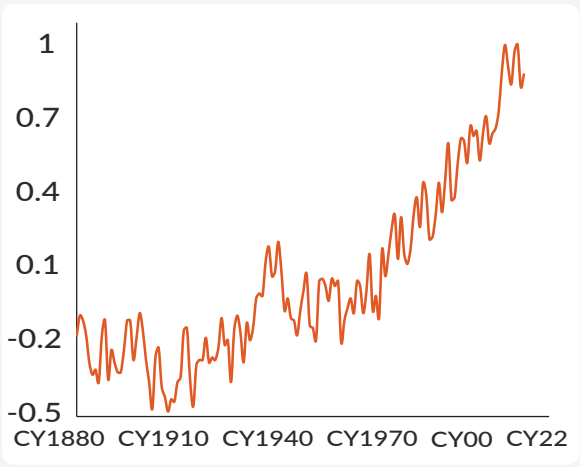
Exhibit 1.1

Unwarranted human activities have raised the atmospheric concentration of GHGs leading to a rise in global temperature, requiring immediate call to action

Global Atmospheric CO_2 composition
(ppm, CY1990-20)



Global average surface temperature
(°C, CY1880-22)



Sources(s): NASA data, IPCC, World Meteorological Organization, Secondary research, Praxis Analysis

Climate change is a threat to human wellbeing and the health of the planet. Any further delay in concerted global action will miss the brief, rapidly closing window to secure a liveable future.
- Intergovernmental Panel on Climate Change

The challenge of pollution and global warming is no longer the science, or the rate of innovation, but the rate of implementation: We have the clean solutions; now let's bundle them and install them
- Jens Martin Skibsted

We are the first generation to feel the effect of climate change and the last generation who can do something about it.
- Barack Obama, Former US President

While the problem can sometimes seem overwhelming, we can turn things around — but we must move beyond climate talk to climate action.
- Ted Turner

1.1 Challenges faced by India

In the league of major greenhouse gas (GHG) emitters, China, USA, India, Russia, Brazil, and Indonesia are collectively responsible for over half of the world's GHG emissions. While India's extensive land area may suggest a more distributed impact, it is noteworthy that India stands as the third largest GHG emitter per square kilometer among these nations.

The transportation sector plays a pivotal role, contributing around 10% of India's total emissions, as illustrated in Exhibit 1.2. This sector is particularly pressing for India, given the country's alarming air quality. Notably, India is home to 14 of the world's most polluted cities, with New Delhi, the capital, ranking as the 8th most polluted globally.

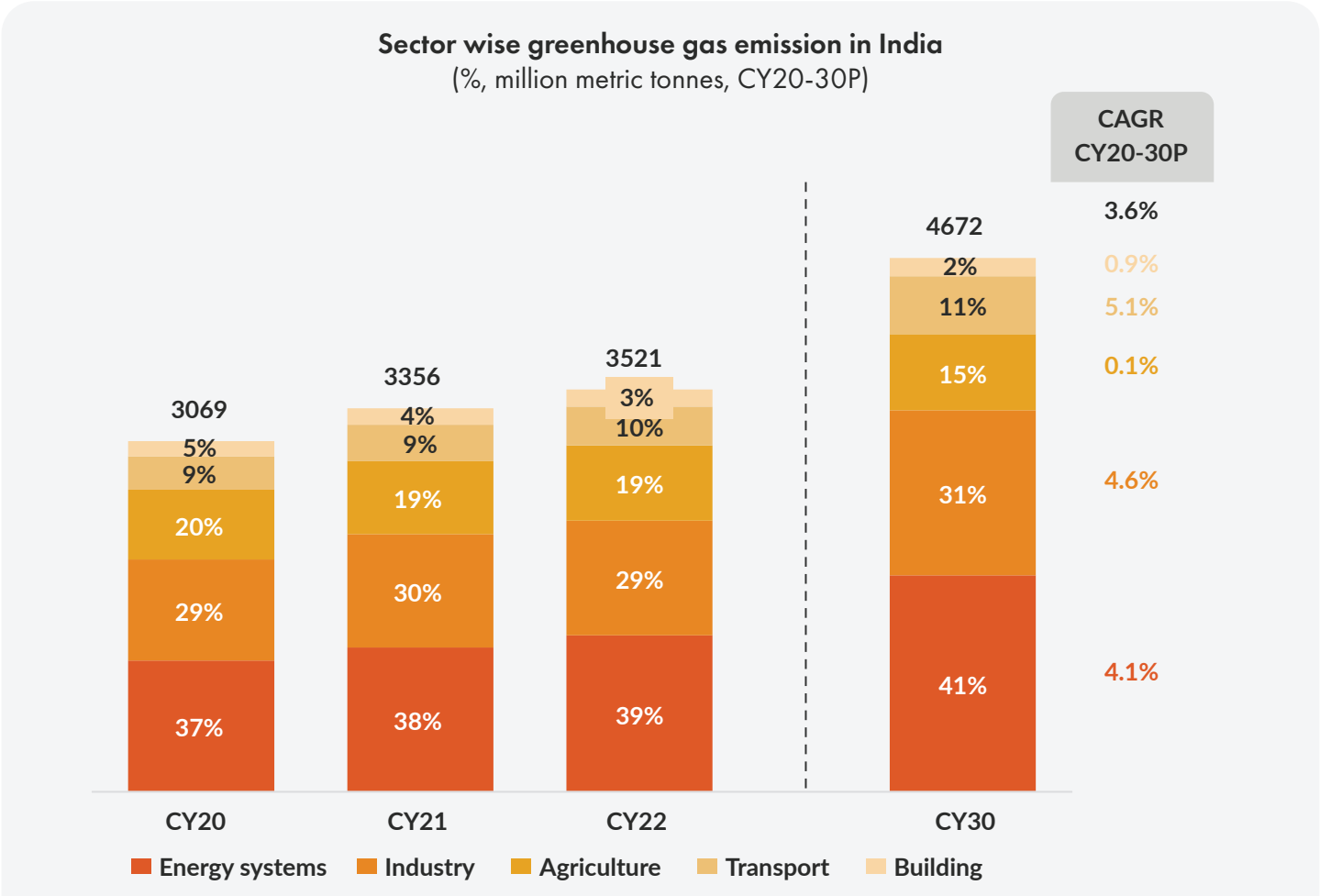
Compounding the issue, forecasts reveal a worrisome trend. GHG emissions from India's transportation sector if left unchecked are expected to rise at an alarming Compounded Annual Growth Rate (CAGR) of 5% until 2030. Within this sector, road transport takes the lead, contributing a staggering 80% of these emissions.

Beyond environmental concerns, India grapples with economic vulnerabilities due to heavy oil dependence. An import bill of 3-4% of GDP, driven by a staggering US$158 billion spent on crude oil imports in 2023, poses a significant risk. Fluctuating oil prices directly impact everyday expenses, driving inflation, while geopolitical tensions and supply constraints further complicate the energy security landscape.

The quest for alternative and sustainable energy sources is now an imperative, not just for environmental reasons but as a strategic move towards a resilient and sustainable energy future.

Exhibit 1.2

GHG emission from transportation sector is likely to increase by a CAGR of ~5% till CY30P



Source(s): CEEW, Ourworldindata .org, IEA, Secondary research, praxis Analysis

1. Introdcution
2. **Biofuels**
    - Bioethanol
    - Biodiesel
    - Compressed biogas
3. Green Hydrogen
4. Conclusion

2.1 Introduction to biofuels as alternatives to fossil fuels

India's substantial demand for fossil fuels, primarily diesel, petrol, and LPG, which constitute approximately 70% of the country's fossil fuel consumption, has given rise to the exploration of multiple alternatives to traditional fossil fuels. The demand for these conventional fuels has shown a consistent upward trajectory over the years, highlighting the necessity of finding sustainable, environmentally friendly alternatives. Fossil fuels have long dominated the Indian energy landscape, serving as the primary source of power for transportation and various industries.

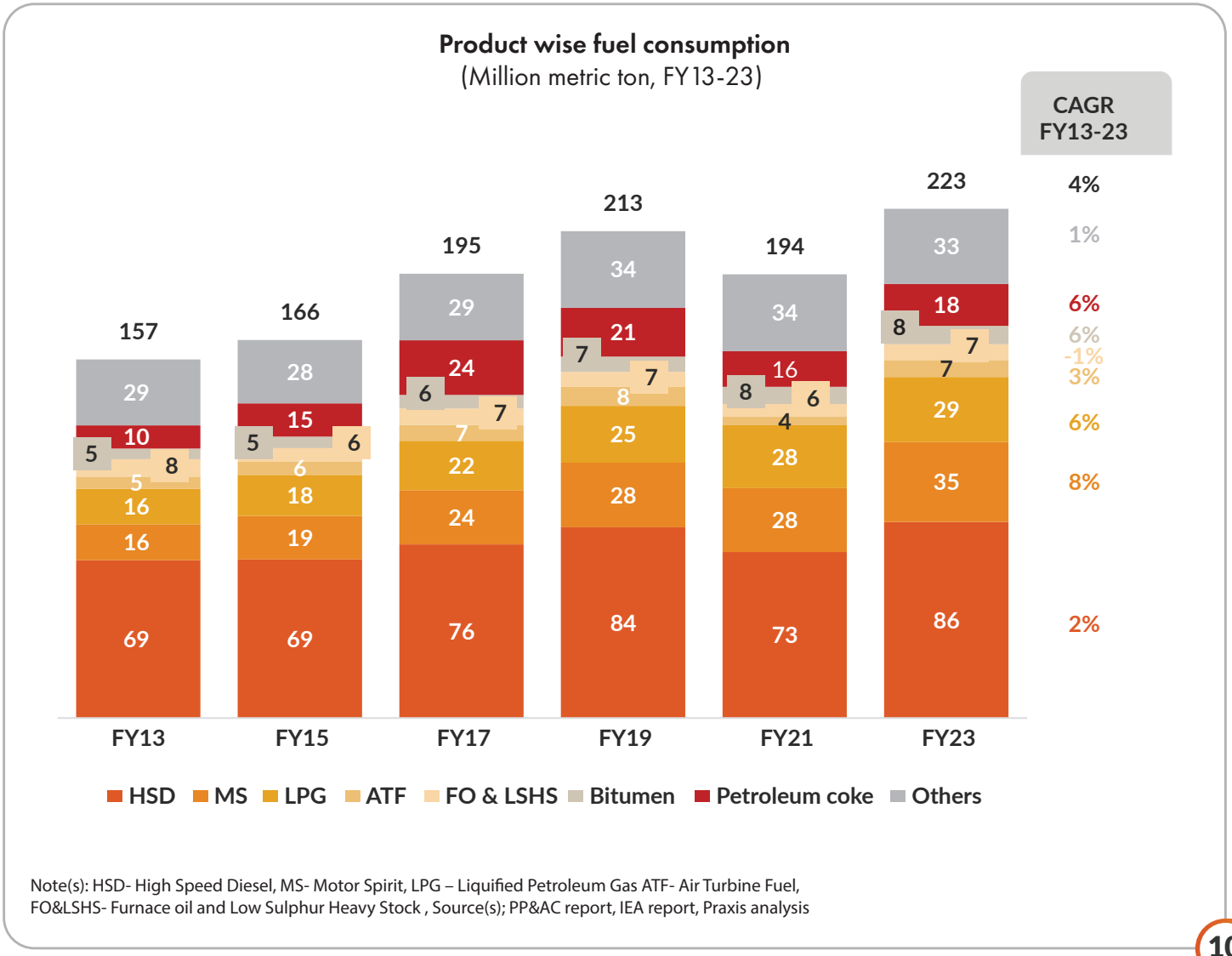
Exhibit 2.1 illustrates the product-wise fuel consumption in million metric tonnes in India from FY13 to FY23, showcasing the dominant role played by diesel, petrol, and LPG in the country's energy mix.

In light of these growing challenges, the pursuit of alternative renewable fuels has become increasingly vital. India, like several other countries, is exploring a range of eco-friendly and sustainable alternatives to replace fossil fuels, ensuring energy security, environmental preservation, and reduced greenhouse gas emissions.

While several alternative renewable fuels are being explored to replace fossil fuels, they present varying levels of feasibility. Biofuels, however, emerge as a promising option with the potential to act as an alternative fuel source across all modes of transportation, thus playing a significant role in India's ongoing energy transition

Exhibit 2.1

Diesel, Petrol & LPG forms ~70% of total fossil fuel consumption in India



Note(s): HSD- High Speed Diesel, MS- Motor Spirit, LPG – Liquified Petroleum Gas ATF- Air Turbine Fuel, FO&LSHS- Furnace oil and Low Sulphur Heavy Stock , Source(s); PP&AC report, IEA report, Praxis analysis

Exhibit 2.2 highlights the feasibility of different renewable fuels as replacements for specific fossil fuels. It demonstrates that biofuels, like ethanol, biodiesel, and biogas or compressed biogas (CBG), are favorably positioned for replacing traditional fossil fuels. The biofuel sector shows great promise in addressing the challenges posed by diesel, petrol, and LPG, which are the primary contributors to India's fossil fuel consumption.

Exhibit 2.2

Alternate renewable fuels present different level of feasibility to displace fossil fuels; biofuels can act as an alternate fuel to all modes of transportation

Fossil fuels

		HSD	MS	LPG	ATF	FO & LSHS	Bitumen	Petroleum coke
Electricity	Solar energy	✓	✓	✓	×	✓	×	✓
	Wind energy	✓	✓	✓	×	✓	×	✓
	Hydropower	✓	✓	✓	×	✓	×	✓
	Geothermal	✓	✓	✓	×	✓	×	✓
	Tidal & wave energy	✓	✓	✓	×	✓	×	✓
Biofuels	Ethanol	✓	✓	✓	×	×	×	✓
	Biodiesel	✓	×	✓	×	✓	×	✓
	Biogas / CBG	✓	✓	✓	×	✓	×	✓
	Sustainable aviation fuel	×	×	×	✓	×	×	×
Hydrogen energy	H_2Power	✓	✓	✓	✓	✓	×	✓

✓ Low feasibility ✓ High feasibility × Not-feasible

Note(s): HSD- High Speed Diesel, MS- Motor Spirit, LPG – Liquified Petroleum Gas ATF- Air Turbine Fuel, FO&LSHS - Furnace oil & Low sulphur heavy stock

Source(s); PP&AC report, IEA report, Praxis analysis

2.2 Adoption of biofuels globally and domestically

India is among the key players in the global shift towards biofuels, alongside countries such as the USA, Brazil, Indonesia, and Canada. Together, they account for approximately 75% of global biofuel consumption. The growing demand for biofuels is evident, as global consumption has witnessed a significant rise from 174 billion metric tonnes in 2016 to 223 billion metric tonnes in 2023. Over the years, the demand for biodiesel, in particular, has seen rapid growth, boasting a Compound Annual Growth Rate (CAGR) of approximately 9%. In the context of total biofuel consumption, ethanol has a significant contribution, representing about ~50% of the total consumption followed by biodiesel at 30%.

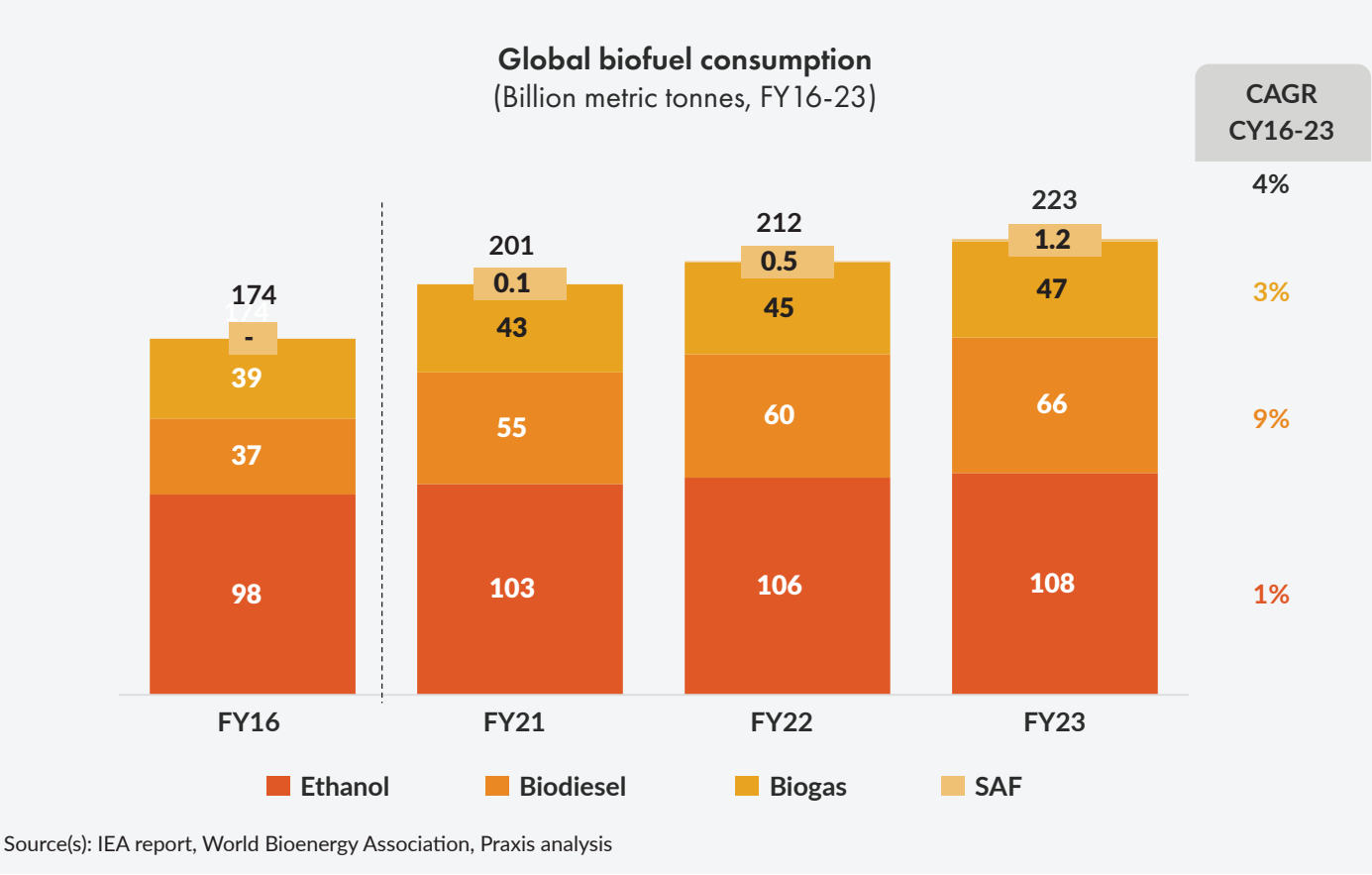
India holds a 3% market share in global biofuel consumption driven by the government's commitment to achieving a 20% ethanol blend by 2025 and a 5% biodiesel blend by 2030. This aligns with India's energy security objective by reducing the nation's dependence on imported crude oil, which accounted for 87% of domestic demand in 2023.

Indian Government's blueprint for biofuels

Government policy support and clear guidelines have been instrumental in the adoption of biofuels across multiple countries, including India, the USA, and Brazil. The Indian government implemented the National Policy on Biofuels in 2018, mandating a 10% ethanol blend by 2023. This policy also guarantees ethanol pricing, provides feedstock guidance, and supports investment in the sector. India's production capacity ranks third globally for both ethanol production and consumption, although it lags behind in biodiesel adoption. The country has set ambitious targets, aiming to increase ethanol blending to 20% by 2023 and biodiesel blending to 5% by 2030. In 2022, India amended its National Policy on Biofuels to expedite the adoption of E20 by 2025 and B5 by 2030.

Exhibit 2.3

Demand for biodiesel is increasing rapidly at a CAGR of ~9% & contributing ~30% of total biofuel



Source(s): IEA report, World Bioenergy Association, Praxis analysis

US Government's initiatives

USA has established its position as the largest global producer of biofuel, generating 70 billion litres annually, equivalent to 15% of the energy supply based on gasoline and diesel. Key initiatives, such as the Renewable Fuel Standard (RFS), mandate fuel distributors to sell renewable fuel according to their market share. The introduction of the Inflation Reduction Act (IRA) further supports production, investment, and tax credits for biofuels. USA aims to increase ethanol blending to 15% and set a target of 11 billion litres for sustainable aviation fuels by 2030. Additionally, innovative technologies that utilize waste and oils for advanced biodiesel production are on the horizon.

Brazil Government's initiatives

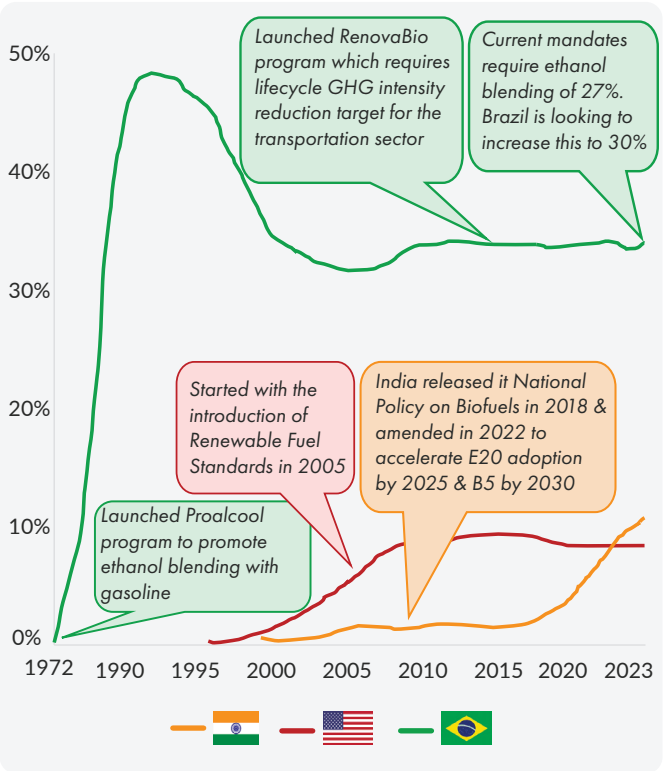
As the second-largest biofuels producer globally, Brazil supplemented 22% of its transport energy needs in 2022 through biofuels. Initiatives such as the Fuel of the Future, Proalcool and RenovaBio program promote ethanol blending with gasoline and intensity reduction in the greenhouse gas lifecycle for the transportation sector. Brazil's mandates for ethanol blending are currently at 27%, with plans to increase to 30%, while biodiesel blending targets have been progressively increased from 2% in 2005 to 12% in 2023, with a 15% target by 2026. Brazil has also introduced preferential tax treatments for flex-fuel vehicles, as well as preferential tax treatment for ethanol compared to gasoline under federal taxes. Moreover, the Brazilian National Bank for Economic and Social Development (BNBSED) provides credit lines for investments in sugar, ethanol, and feedstock.

The adoption of biofuels has been a pivotal part of these countries' sustainability agendas and energy security objectives as illustrated in Exhibit 2.4. Thus, highlighting that it is essential for India to continue aligning its strategies with these global leaders in the biofuel sector in order to achieve its energy transition goals.

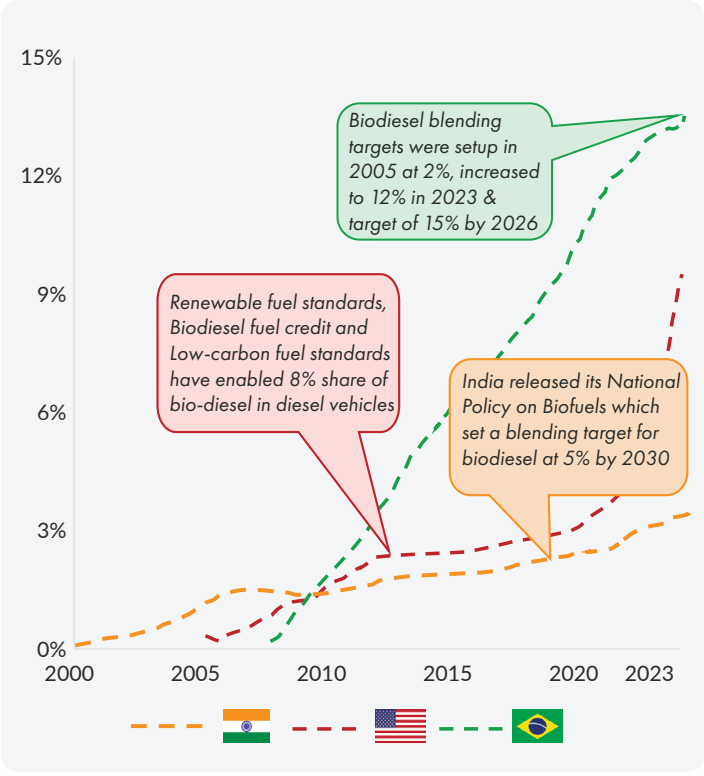
Exhibit 2.4

Government policy support & clear guidelines have been key enablers in adoption of biofuels across India, USA & Brazil

Policy impact on adoption of ethanol in India, USA & Brazil
(%,1972-2023)



Policy impact on adoption of biodiesel in India, USA & Brazil
(%,2000-2023)



Note(s): India has setup of Sustainable Aviation Fuel roadmap to produce 11B L fuel by 2030
Source(s): IEA report, Praxis analysis

1. Introdcution

2. Biofuels

Bioethanol

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Compressed biogas

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2.3.1 What is bioethanol and ethanol blending?

Bioethanol, commonly referred to as ethanol, is a sustainable, renewable fuel produced through the fermentation of organic materials, including crops, grains, sugarcane, and agricultural waste. It has emerged as an eco-friendly alternative to conventional gasoline, primarily due to its ability to significantly reduce greenhouse gas (GHG) emissions.

Ethanol blending is a vital strategy that involves mixing ethanol with petrol in specified ratios, such as E10 (10% ethanol + 90% petrol). India successfully achieved the target of 10 percent ethanol blending by November 2022, marking a pivotal step in the nation's pursuit of cleaner energy. Looking ahead, India envisions achieving 20% ethanol blending (E20) by 2025-26, as part of its commitment to greener, more sustainable transportation fuel.

2.3.2 Government initiatives to support ethanol blended petrol

The Indian government has taken significant steps to bolster the adoption of Ethanol Blended Petrol (EBP). These initiatives are aimed at enhancing both the supply and demand sides of the ethanol market.

Supply-side initiatives

To regulate prices and safeguard the interests of stakeholders, the government is actively developing supply chain mechanisms, feedstock collection centers, and fair price mechanisms. These initiatives are conducted in close coordination with local bodies, states, and relevant stakeholders. For instance, mechanisms like Fair and Remunerative Price (FRP) for setting ethanol prices have been introduced, on the basis of the feedstock being used.

An interest subvention scheme has been approved to encourage the establishment of new distilleries or the expansion of existing ones, along with other activities related to ethanol production. Under this scheme, interest subvention on loans is provided at a rate of 6% per annum or 50% of the interest rate charged by banks, whichever is lower.

Additionally, the government is actively setting up new ethanol production plants under the PM-JIVAN scheme, focusing on areas with ample biomass availability. This strategic move ensures that ethanol remains readily accessible for blending across the country.

Demand-side initiatives

On the demand side, the government mandates a minimum percentage of ethanol blending with gasoline fuel. Simultaneously, it encourages the production of ethanol-compatible vehicles.

To further incentivize the adoption of ethanol-compatible vehicles, the government is contemplating tax benefits for E20-compatible vehicles. This measure aims to mitigate the cost increase associated with E20-compatible design, aligning with similar initiatives in some states to promote electric vehicles.

In an effort to make ethanol-blended gasoline more attractive to consumers, the government is considering tax breaks and lower retail prices for these blended fuels compared to regular petrol. These initiatives collectively drive the broader acceptance of ethanol blended petrol, marking a crucial step toward a greener and more sustainable energy future.

2.3.3 Key highlights of E10 blending

The government initiatives to boost E10 ethanol blending has yielded numerous advantages, including a significant reduction in GHG emissions, equivalent to approximately 32 million metric tons in India since 2014. This translates into a cleaner and healthier environment. Furthermore, it has contributed to a substantial reduction in India's fossil fuel import bill, saving an estimated INR 54,000 crore and enhancing the country's energy security. Notably, the program has also had a positive impact on the income of farmers, with nearly INR 17,000 crore disbursed during the Ethanol Supply Year 2022 (ESY22). Additionally, the Ethanol Blending Program (EBP) has spurred economic growth by promoting the establishment of over 100 new distilleries and boosting the small and medium-sized enterprise (SME) sector. Ethanol production capacity has surged by over 2.5 times, and the number of distilleries has grown by 66% in just 8 years, with a total of 262 distilleries in operation in 2022.

2.3.4 Bioethanol production and opportunities across the value chain:

Bioethanol is produced through two primary methods based on feedstock: molasses-based and grain-based. Molasses, a byproduct of sugar production, serves as the feedstock in the molasses-based approach. The fermentation of molasses with yeast cells called zymase takes around 2-3 days, yielding ethanol, carbon dioxide (CO_2), and heat. The resulting solution is then distilled to obtain azeotropic alcohol.

In the grain-based method, crops such as rice, maize, or damaged grains are milled into flour. This flour is then processed into a slurry and subjected to liquefaction. The resulting mash is then fermented to produce ethanol. India hosts over 260 molasses-based and more than 100 grain-based ethanol manufacturing distilleries, with storage occurring in large tanks at regulated temperatures. The collective storage capacity is approximately 430 crore litres, providing a 15-day coverage period for annual handling.

The entire bioethanol value chain teems with opportunities following the launch of the E20 program. In the feedstock stage, these opportunities span from the sale of crop residues and the production of essential farming equipment to the supply of carrier materials like gunny bags and poly sacks, as illustrated in Exhibit 2.5.

Exhibit 2.5

Multiple opportunities exist in the ethanol blending sector throughout the value chain from production, storage, and blending process

	Feedstock	Production	Storage	Distribution	Utili-zation	EBP
Business opportunities	• **Sale of crop residue** from fields, plantations • Scope for **production of equipment** like axe, crowbar, sickle etc • **Production and supply of carrier materials** like gunny bags, poly sacks	• **Production facilities and machinery** equipment • **Enzyme and Yeast supply** for the production process • **Ethanol dehydration technology** • Development and utilization of **waste heat recovery** can enhance energy efficiency and sustainability	• Construction of new **storage tanks** near production facilities • Storage **tank maintenance** • **Compliance and safety consulting** services	• **Logistics services** for feedstock and ethanol mobilization • Recruitment of **licensed drivers** • Emergency **response and spill management**		• Setting up and operation of **ethanol blending stations** • **Fuel retailing and distribution** via partnerships with existing retailers / establishing a new network • **Blending equipment and technology** • **Quality control services**
Stakeholders benefitted	• Farmers and plantation owners • Feedstock contractors/ collection aggregators • Cottage units (gunny bags/ poly sack supply)	• Processing facility and management • Service technicians • Machinery manufacturers	• Processing facility and management • Service technicians • Machinery manufacturers	• Authorized vehicle dealers/ company outlets • Private transport agencies • Automobile companies • Vehicle service centres		• Fuel retailers • Station operators • Consumers • Technology providers • Environmental and sustainability advocates
Players	Food Corporation of India	Shree Renuka Sugars, Balrampur Chini Mills Limited, Triveni Engineering & Industries Ltd., Parrys, Dwarikesh Sugar Industries Limited, bajaj Sugar, Dhampur Legacy for tomorrow, Dalmia Bharat Sugar, HBL Infocl Biofuels Ltd, Globus Spirits				Bharat Petroleum, HP, IndianOil, Reliance Industries Limited Growth is Life

Involved in both production and storage

Source(s): MOP&NG Ethanol booklet, PIB release, Industry reports, Praxis analysis

The production phase holds the potential for the establishment of production facilities, enzyme and yeast supply for ethanol production, and the enhancement of energy efficiency via waste heat recovery methods. Storage offers chances for constructing new storage tanks and delivering maintenance and safety consulting services. Meanwhile, the distribution segment presents opportunities in logistics services, driver recruitment, and emergency response services.

Within the utilization and Ethanol Blending Programme (EBP) phase, opportunities abound with the establishment of blending stations, fuel retailing and distribution, blending equipment and technology, and quality control services

2.3.5 Demand and supply analysis of E20 program

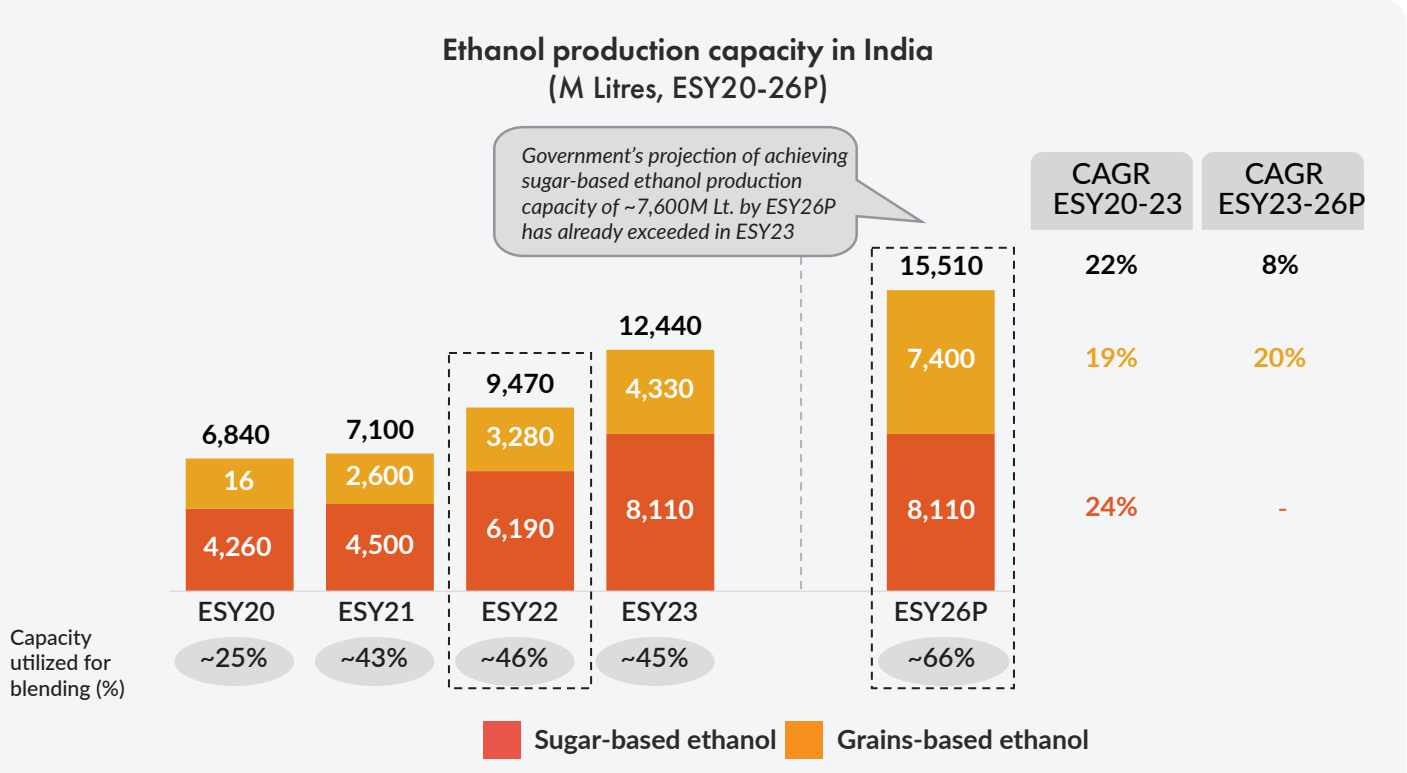
In response to the growing demand for cleaner and sustainable energy sources, the Government of India (GoI) is implementing significant measures to bolster the production and supply of ethanol. The ambitious plan is to increase the production capacity to a substantial 15,510 million litres, accompanied by a remarkable 2.3-fold increase in ethanol supply to Oil Marketing Companies (OMCs) to meet the E20 target. Referring to exhibit 2.6, as it stands, approximately 45% of the current 12,440 million litres capacity caters to the E10 demand. The GoI envisions expanding this capacity to more than 15,510 million litres to accommodate the requirements of E20 fuel, marking a pivotal shift toward a cleaner and more sustainable energy source.

India's ethanol production capacity has witnessed consistent growth and has surpassed the government's projections. The government had set a target of achieving a sugar-based ethanol production capacity of approximately 7,600 million litres by the Ethanol Supply Year 2026 (ESY26P), which was remarkably achieved by 2023 (ESY23). To put this into perspective, India was successful in meeting its E10 demand in 2022 (ESY22).

However, to fulfil the burgeoning E20 demand estimated by ESY26, a substantial 2.3-fold increase in supply is imperative. The supply of ethanol to OMCs, categorized into sugar-based and grains-based ethanol, is projected to reach a remarkable 10,160 million litres, in alignment with the demand-side requirements for E20, as illustrated in Exhibit 2.7.

Exhibit 2.6

46% of the current 9,470M litres capacity is used for E10 demand, GoI aims to increase it to 15,000+M. Litres for E20



Note(s): ESY = Ethanol Supply Year is considered from December to November every year
Source(s): MOP&NG Ethanol booklet, PIB release, Industry reports, Praxis analysis

Several compelling drivers underscore the adoption of ethanol as a biofuel in India. The primary reason being the imperative need to reduce dependence on imported fossil fuels. The government's implementation of favourable policies, including the National Biofuels Policy of 2018 and the Ethanol Blended Petrol Program, has been pivotal in accelerating the production and use of ethanol as a sustainable energy source. Economic support to farmers has expedited payments for ethanol, amounting to around INR 16,793 crore during ESY22-23, with a promising projection of approximately INR 42,000 crore by ESY25-26, highlighting the government's unwavering commitment to supporting the bioethanol sector.

Leveraging surplus feedstock and production capacity is another major driving force behind the ethanol industry. India's surplus stock of sugar reached approximately 4.3 million metric tons in ESY22-23 and is projected to increase to around 6 million metric tons by ESY25-26, providing ample resources for ethanol production. Diversifying feedstock options is a significant focus, with ethanol production moving beyond cane molasses to encompass various feedstocks such as rice, maize, and other grains. This diversification can help reduce the nation's reliance on water-intensive crops, promoting sustainability and water conservation.

2.3.6 Impact across stakeholders

The transition from E10 to E20 fuel in India promises a multitude of positive impacts across various stakeholders:

a) **Environmental benefits:** E20 fuel adoption is set to significantly reduce greenhouse gas emissions. Vehicles running on E20 emit lower levels of carbon monoxide and hydrocarbons, contributing to a cleaner and more sustainable environment.

b) **Income diversification for farmers:** This shift provides farmers with an opportunity to diversify their income sources by supplying agricultural waste materials for ethanol production. This not only boosts their earnings but also promotes sustainable agricultural practices.

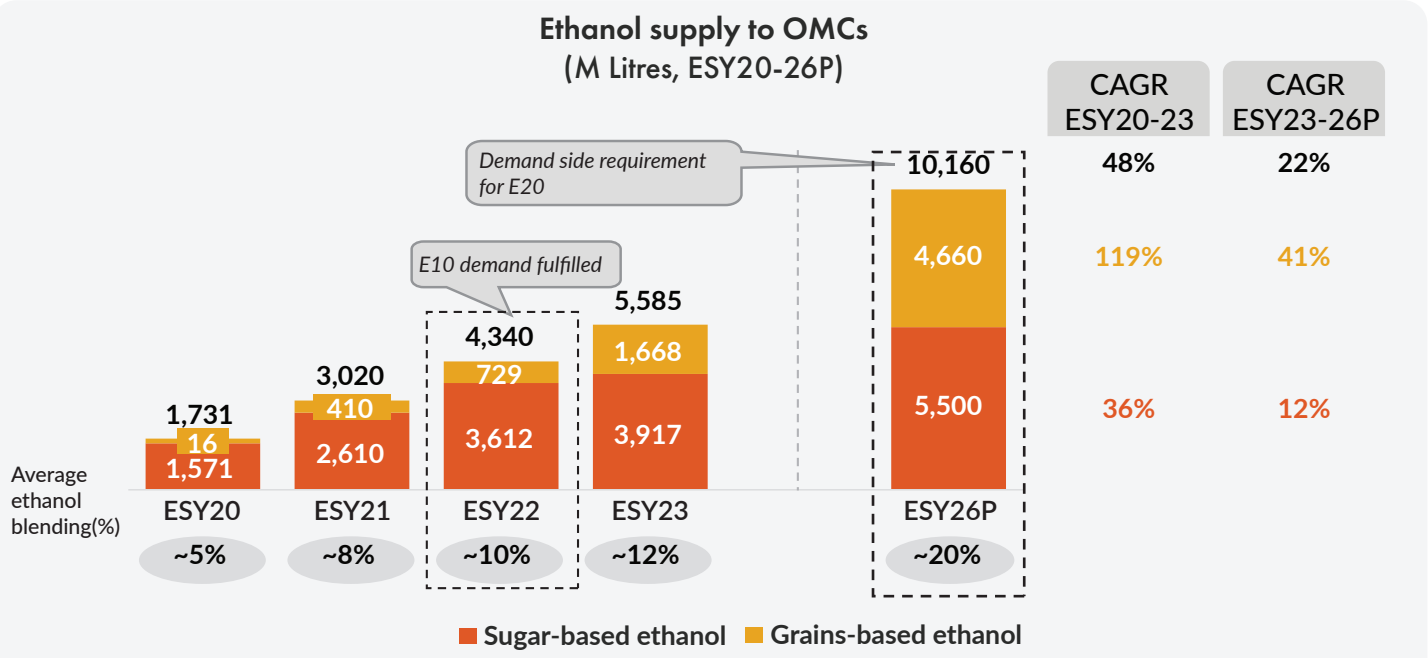
c) **Business opportunities**: Ethanol producers and entrepreneurs are set to benefit as the transition guarantees a steady market for ethanol sales. It also opens opportunities for entrepreneurs to invest in and establish ethanol manufacturing plants to meet the growing demand for cleaner fuels.

d) **Cost savings for oil marketing companies (OMCs):** OMCs can reduce their fuel import costs by incorporating cost-effective ethanol into their fuel blends. This move not only lowers operational expenses but also supports national energy security goals.

The transition to E20 fuel is anticipated to bring about a wealth of benefits to stakeholders and encompasses environmental benefits. However, there are certain challenges that must be overcome for smoother adoption.

Exhibit 2.7

In ESY22, India fulfilled its E10 demand, but to meet the E20 demand by ESY26, a 2.3x increase in supply is required



Note(s): ESY = Ethanol Supply Year is considered from December to November every year
Source(s): MOP&NG Ethanol booklet, PIB release, Industry reports, Praxis analysis

2.3.7 Challenges in adoption and mitigation measures

a) **Reliance on sugar-based feedstock:** A significant challenge is the current reliance on sugar-based feedstock, which is seasonal, price-sensitive, and water-intensive. To mitigate this, the government is encouraging the production and usage of maize and other low-water-consuming feedstocks. Additionally, it is setting up 12 second-generation ethanol manufacturing plants based on agricultural waste.

b) **Limited production:** The current ethanol manufacturing capacity is considerably low compared to the upcoming demand. To address this, the government is expediting regulatory clearances for ethanol-producing units and promoting the establishment of more ethanol manufacturing units.

c) **Non-uniform availability and restricted ethanol movement:** Ethanol is not uniformly produced or available in some states, especially in the northeastern states, which poses a challenge for ethanol blending. The central government has amended the Industries Development and Regulations Act to ensure the transportation of ethanol across the country. However, only 14 states have implemented these provisions. The government is urging all states to implement these amendments to facilitate inter-state ethanol movement and ensure uniform availability.

d) **Limited storage capacity:** The current storage capacity is insufficient to meet the E20 demand for ethanol. Oil Marketing Companies (OMCs) have been tasked with expanding tankage capacity, with plans to incorporate an additional 27 crore litres of storage.

e) **Need for E20-compatible vehicles:** Vehicle manufacturers need to develop ethanol-compatible parts, optimize engines for higher ethanol blends, and invest in introducing E20-compliant vehicles. To ensure that E20-tuned engines are rolled out across the country from April 2025 without compromising performance, vehicle manufacturers are actively collaborating with the government.

f) **Widespread acceptability by customers**: The lower calorific value of ethanol compared to petrol may lead to a drop in fuel efficiency and vehicle performance, especially in low-powered two-wheelers. To enhance the acceptability of higher ethanol blends, the retail price of E20 will be lower than regular petrol to compensate for the reduced calorific value. Vehicles compliant with higher ethanol blends may also receive tax benefits, further encouraging their use.

1. Introdcution

2. Biofuels

- Bioethanol
- **Biodiesel**
- Compressed biogas

3. Green Hydrogen

4. Conclusion

2.4.1 What is biodiesel and biodiesel blending?

Biodiesel is a renewable fuel produced through a process known as transesterification, which involves reacting vegetable oil or animal fat with alcohol in the presence of a catalyst. This method generates biodiesel with good combustion properties, making it a cleaner substitute for traditional hydrocarbon-based diesel. Biodiesel is mixed with diesel in specific ratios, such as B5, B10 and B20 (5%, 10% and 20% biodiesel blended with traditional diesel).

While biodiesel possesses approximately 9/10th of the calorific value of traditional diesel (with a calorific value of 41.63 MJ/Kg for B100 blend and 45.50 MJ/Kg for B0), it significantly outperforms in terms of environmental impact. Biodiesel reduces GHG emissions by 50-75%, resulting in lower CO_2 and hydrocarbon emissions, particularly in B5 fuel. Importantly, vehicles do not require major modifications to be compatible with B5 biodiesel, ensuring a seamless transition to cleaner fuel.

The Indian government has laid out an ambitious roadmap to achieve 5% biodiesel blending with conventional diesel by 2030. The National Policy on Biofuels, 2018, is at the forefront of this initiative. This policy seeks to bolster the use of biofuels in the energy and transportation sectors, emphasizing the use of domestic feedstock, reducing reliance on fossil fuels, and fostering sustainability.

2.4.2 Government initiatives to support

The Indian government is actively promoting biodiesel adoption through a series of strategic initiatives, focusing on both the supply and demand sides.

Supply side initiatives

The 2018 National Policy on Biofuels, which prioritizes non-food feedstocks to prevent conflicts between food and fuel production while fostering rural development and environmental benefits. Additionally, the National Biofuel Mission (NBM) facilitates the phased expansion of Jatropha and Pongamia feedstock cultivation and manages various aspects of crop production, oil extraction, blending, trade, and research. The government encourages Foreign Direct Investment (FDI) by allowing 100% foreign equity for biodiesel production with the condition that the produced biofuels are used domestically. Import and export restrictions have been implemented to safeguard the interests of domestic feedstock and biodiesel producers, thus promoting domestic production and availability. Furthermore, the introduction of a Minimum Support Price (MSP) for Jatropha seeds ensures fair remuneration for growers.

Demand side initiatives

On the demand side, the National Biofuels Development Board (NBDB) formulates a comprehensive roadmap for the utilization of biofuels in both petrol and diesel engines, accompanied by relevant policy implementation. The Biodiesel Blending Programme (BDBP) seeks to achieve 5% biodiesel blending with diesel, thereby facilitating the transition from fossil fuels to biofuels within the transportation sector. Moreover, the government provides tax concessions and subsidies, including zero excise duty, a reduced Goods and Services Tax (GST) rate, and production subsidies, aimed at incentivizing and promoting the adoption of biodiesel. These multifaceted measures illustrate the government's dedicated efforts to realize a cleaner and more sustainable energy future.

2.4.3 Expected benefits of the biodiesel blending program

Adopting biodiesel-blended diesel in India is poised to deliver a multitude of advantages, signifying a major step towards cleaner and sustainable energy. Foremost among these benefits is the substantial reduction in greenhouse gas (GHG) emissions, particularly carbon dioxide (CO_2), amounting to an estimated 32 million tonnes annually by the year 2030. Not only does this reduce environmental impact, but it also ensures a cleaner and healthier environment for the nation. Each litre of 5% biodiesel blended fuel has the potential to save approximately 200 grams of CO_2 emissions. Furthermore, the implementation of the B5 program is projected to yield immense financial savings. It is estimated that by 2030, India could save around INR 41,600 crores on its import bills, significantly enhancing the country's energy security. This cumulative foreign exchange impact further underscores the financial benefits of the B5 program. In addition to these advantages, the program contributes to better waste management by recycling a substantial volume of used cooking oil, reducing environmental harm caused by clogged drains and sewers. India has the potential to recycle approximately 1,400 million litres of used cooking oil from hotels and restaurants, resulting in an annual production of roughly 1,100 million litres of biodiesel. Moreover, this initiative bolsters local industries, with biodiesel production capacity set to increase 27 times to around 5,400 million litres by 2030, providing a significant boost to the small and medium-sized enterprise (SME) sector. These collective benefits signify the transformative impact of biodiesel adoption in India.

2.4.4 Biodiesel production and opportunities across the value chain

Government support across the biodiesel value chain has paved the way for a multitude of opportunities, with a keen focus on used cooking oil (UCO) as a feedstock. In terms of feedstock collection, there's a preference for high-lipid content oils, encompassing not only virgin vegetable oils but also animal tallow, both edible and non-edible, as well as microbial oils. The Indian government is actively pursuing a shift from the prevalent use of imported palm stearin oil to UCO. In addition, the cultivation of tree-borne oilseed feedstock on previously unused or infertile land is a prospective route to bolster feedstock self-reliance, as illustrated in Exhibit 2.8.

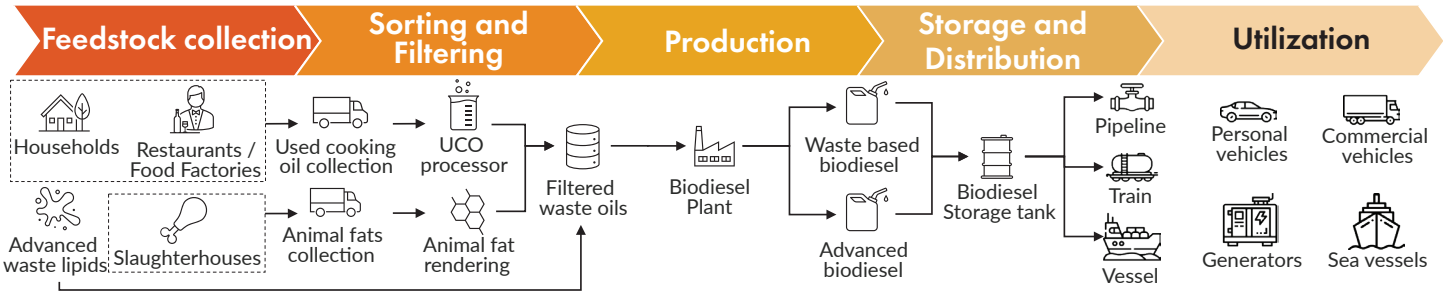
Efficient sorting and filtering are crucial steps in the value chain, given that India annually generates 3 million metric tons of UCO, a significant portion of this UCO ends up diverted to informal markets, perpetuating health concerns.

To rectify this, the government's intervention includes establishing a Minimum Support Price (MSP) for UCO, incentivizing biorefinery sales, market regularity, and curbing illegal activities.

Policy-backed innovation, the creation of UCO feedstock collection networks, and the promotion of UCO-based biodiesel startups represent pivotal developments in the

Exhibit 2.8

Government support have created opportunities across the biodiesel value chain, with focus on UCO feedstock collection, processing, and production



- **High lipid content oils** like virgin vegetable oils are preferred for producing biodiesel
- **Animal tallow,** edible / non-edible, and **microbial oils** can be used as feedstock
- Currently, **imported palm stearin oil is the primary feedstock;** the Indian government aims to replace it with used cooking oil (UCO)
- Cultivating **tree-borne oilseed feedstock on wasteland or infertile land** has the potential **to foster feedstock self-reliance**

- **India generates 3M metric tons of used cooking oil (UCO) annually.** This oil is often **sold to street vendors and small-town markets** instead of reaching the biodiesel industry
- **The government should establish a Minimum Support Price (MSP) for used cooking oil (UCO)** to **incentivize sales to biorefineries,** regularize the market, and **counter illegal activities by oil mafias**

- **Policy support for innovation** can help raise technology readiness and accelerate commercialization
- Establishing a **collection network for UCO feedstock** can enhance raw material availability, reduce uncertainty, and contribute to stable biodiesel production
- **Promoting UCO-based biodiesel startups and government procurement of UCO-derived biodiesel** can drive production volume

Across feedstock collection, filtering and production

- **B100 biodiesel can degrade and weaken hoses, gaskets, seals, elastomers, glues,** and plastics over time, so it's essential to choose **appropriate materials for storage**
- **Stainless Steel, mild steel, and Aluminum** have shown **acceptable resistance to corrosion by B100**
- **Transporting biodiesel in cold weather can be challenging,** and precautions should be taken to prevent freezing during transit

- The Indian government intends to **mandate automobile manufacturers to produce vehicles compatible with B100 fuel**
- **High-quality biodiesel usage in construction and mining equipment**
- **Easing import-export restrictions on biodiesel** can foster international collaboration and open new market opportunities
- Promoting **biodiesel as an energy source in various industrial processes** can create new avenues for demand

Emerging players

Across feedstock collection, filtering and production: K. Nandi Refinery; G-Energetic Biofuels; Khanda Biofuels; Biodiesel; AGF; biodiesel; WASHWELLBIO; Universal Biofuels; Abellon; emami; Blue Stone Energy; aris Biochem; Eco Green Fuels Pvt. Ltd.; MÜNZER; Go Green Fuel; BiOD

Distribution and storage: Greenergy; Hindustan Biofuel; PureFuel Energy; Chemical Construction International (P) Ltd.

Utilization: Bharat Petroleum; HP; IndianOil; Reliance Industries Limited

Source(s): EWABA, FSSAI, ADB, USDA FSA, Bharat Petroleum Report, Press releases, Company website, Secondary research and Praxis analysis

biodiesel production phase. The government's extensive support and commitment to procure UCO-derived biodiesel contribute to overall production volume.

In the storage and distribution phase, material choices for storage are of paramount importance due to B100 biodiesel's potential to degrade certain components over time. Stainless steel, mild steel, and aluminium have demonstrated satisfactory resistance to corrosion by B100. It is also essential to address transportation challenges in cold weather to prevent freezing during transit.

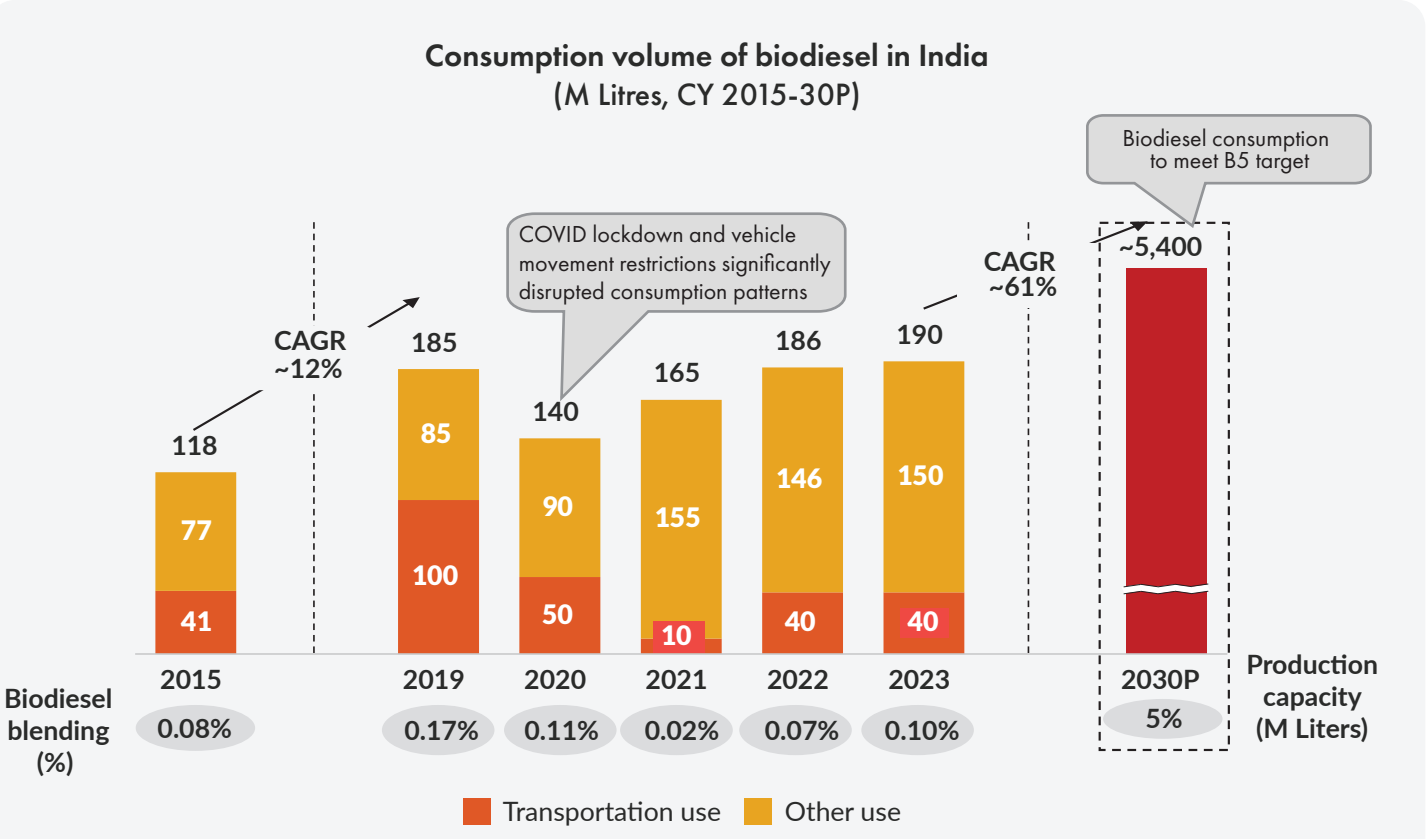
To drive utilization, the Indian government intends to mandate the production of vehicles compatible with B100 fuel by automobile manufacturers. High-quality biodiesel adoption in construction and mining equipment, coupled with eased import-export restrictions, facilitates international collaboration and new market opportunities. Promoting biodiesel as an energy source across various industrial processes opens up fresh avenues for demand and growth in the biodiesel sector.

2.4.5 Demand and supply analysis of the B5 program

India's biodiesel sector, which faced a setback in 2020 due to the pandemic, is now on a promising upward trajectory. Both biodiesel consumption and demand have recovered to pre-COVID levels, reflecting the sector's resilience. However, the current blending rate is relatively modest at 0.1%. The Indian government has set an ambitious target to increase this rate to 5% by 2030, with the objective of substituting traditional diesel with biodiesel. This shift is anticipated to trigger a significant Compound Annual Growth Rate (CAGR) of around 60% in biodiesel consumption to 5,400 million litres, primarily driven by the mandated blending requirement and the nation's commitment to cleaner and more sustainable fuels, as illustrated in Exhibit 2.9.

Exhibit 2.9

B5 blending target will increase the consumption of biodiesel to 5,400 M litres i.e., 28x times the current consumption



Note(s): Minimum production capacity required to meet B5 mandate
Source(s): USDA FAS Biofuels Annual 2023, Secondary research and Praxis analysis

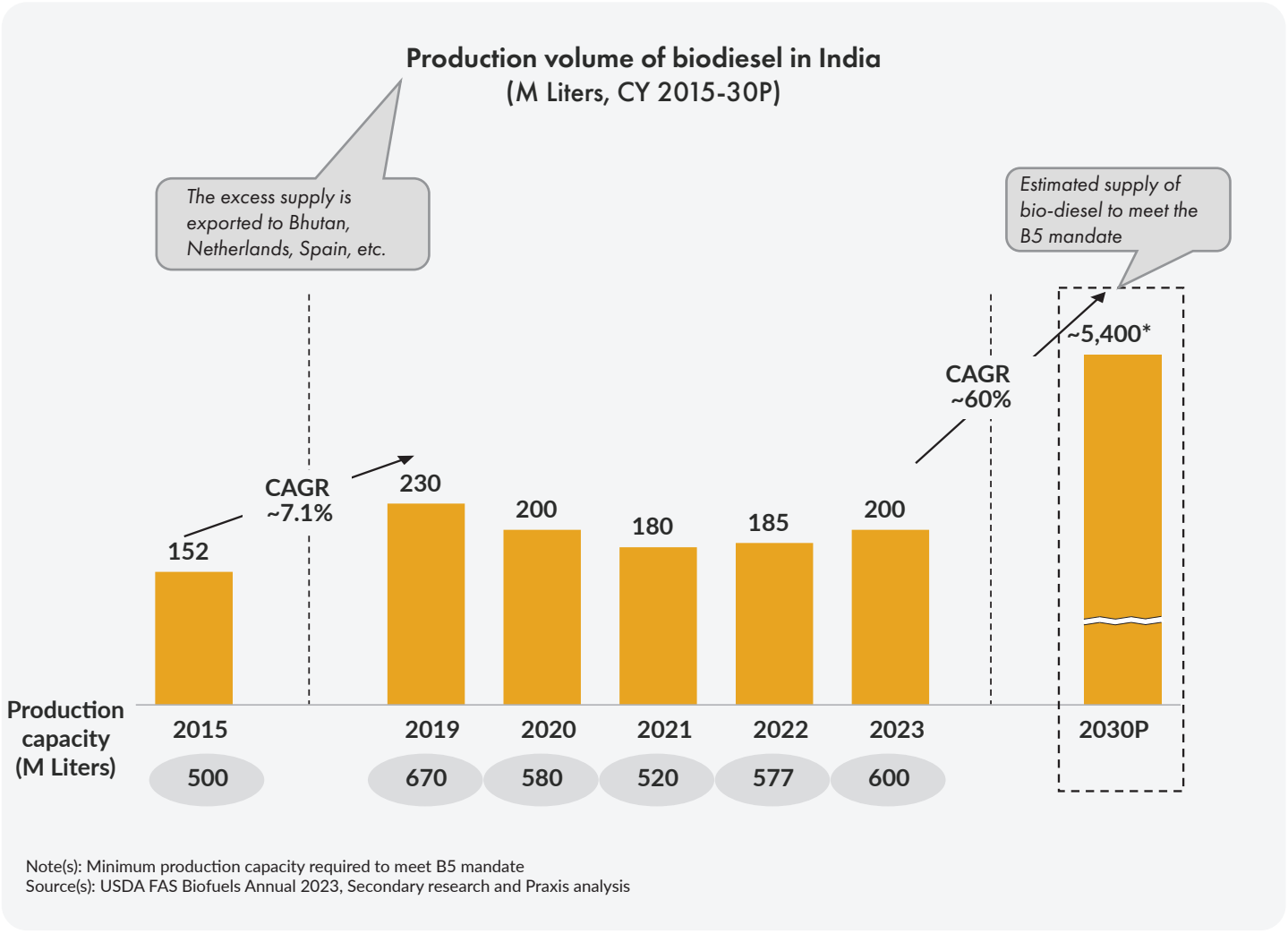
Historical data further underlines the growing trend in biodiesel consumption in India, with consumption volumes reaching an all-time high of 190 million litres in 2023. This achievement underscores the sector's potential for substantial expansion.

However, despite the surging demand, there remains a gap of 10 million litres between supply and demand, as illustrated in Exhibit 2.10. A notable contributor to this gap is India's biodiesel exports to countries like Bhutan, Netherlands, and Spain.

Currently, India's biodiesel production capacity stands at 600 million litres, with only 33% utilization. As India progresses toward the 5% biodiesel blending target, the biodiesel industry is poised to play a pivotal role in shaping the country's energy landscape and to bridge the anticipated supply-demand gap maximizing this existing capacity and ramping up production will be essential. This strategic approach will enable India to meet its biodiesel goals and reinforce its commitment to cleaner and more sustainable energy sources.

Exhibit 2.10

To meet the increased demand for meeting B5 target production needs to grow at a CAGR of ~60% from 2023-30



Note(s): Minimum production capacity required to meet B5 mandate
Source(s): USDA FAS Biofuels Annual 2023, Secondary research and Praxis analysis

2.4.6 Impact across stakeholders

The transition to B5 biodiesel fuel in India is expected to yield significant environmental and stakeholder benefits throughout the value chain.

a) **Feedstock suppliers** will witness increased demand, as the need for feedstock will grow substantially to meet the B5 targets. This rise in demand is expected to lead to higher incomes for suppliers, as well as opportunities to address supply chain gaps for procuring feedstock like used cooking oil.

b) **Biodiesel producers** and energy/fuel companies are gearing up for expansion. The Indian government's Innovation Roadmap of the Mission Integrated Biorefineries outlines plans to establish 12 biorefineries across 11 states, boosting production capacity from the current 600 million litres to 1,382 million litres. The growing demand for biodiesel is poised to unlock new domestic and global market opportunities, leading to job creation and enhanced energy security.

c) **Automakers and OEMs** will benefit from biodiesel's compatibility with existing fuelling infrastructure and improved fuel characteristics, such as enhanced lubricity and a higher cetane rating, making it more efficient.

d) **Retailers, blenders, and importers-exporters** must significantly scale up production capacity and establish efficient supply chains to meet growing demand as India transitions to B5 biodiesel. This surge in demand will create expanded opportunities both nationally and internationally, with cumulative foreign exchange impact resulting in significant savings.

e) **The environment** stands to gain from the transition to B5 biodiesel. Achieving a 5% blend of biodiesel by 2030 is expected to reduce greenhouse gas emissions by approximately 32 million tCO2e per year. If these reductions are carried forward for Clean Development Mechanism (CDM) registration, the projected revenue-earning potential per year from biodiesel could reach US$160 million.

The transition to B5 biodiesel holds the promise of positive impacts on the environment and a wide range of stakeholders involved in the biodiesel value chain. However, there are certain challenges that must be overcome for smoother adoption.

2.4.7 Challenges in adoption and mitigation measures

In pursuit of achieving the B5 target for biodiesel in India, the Government of India (GoI) has devised strategies to bolster the biodiesel industry.

a) **Feedstock supply and pricing challenges:** India faces a scarcity of suitable and consistent feedstock sources, leading to high feedstock prices such as imported palm oil and palm stearin, impacting biodiesel production margins. To address these issues, the government has introduced the Repurpose Used Cooking Oil (RUCO) initiative to increase the procurement of used cooking oil (UCO) for biodiesel production. Oil Marketing Companies (OMCs) have issued Expressions of Interest (EOIs) for biodiesel made from UCOs.

b) **Uncertainty in feedstock cultivation:** Challenges like land transfer issues, material shortages, farmer doubts, and cultivation gaps lead to uncertain yields for biofuel crops. Measures to address this include promoting awareness of the financial benefits and ease of growing non-edible oil crops like Jatropha as feedstocks. Under the National Purchase Policy, OMCs are mandated to purchase biodiesel at import prices.

c) **Incomplete refining and post-processing capabilities:** The absence of key manufacturing capabilities like glycerine refining and methanol recovery affects biodiesel quality and efficiency, particularly in smaller facilities. Biodiesel manufacturing is geographically concentrated in the north, west, and coastal regions, limiting accessibility in other areas. To mitigate these issues, there is a need to promote innovation through fiscal incentives such as tax credits and loan guarantees. Additionally, encouraging Gram Panchayats to establish bio-oil extraction facilities can help improve connectivity.

d) **Inconsistent and inefficient production:** Disruptions in the biodiesel supply chain caused by the COVID-19 pandemic have affected plant capacity. The fragmented biodiesel market and limited domestic production pose challenges in maintaining consistent B5 blending. Significant research is needed to develop supply chain optimization models for biodiesel production. The establishment of a national registry for feedstock availability is necessary to avoid supply-demand mismatches.

e) **Usage challenges and measures:** Challenges related to corrosion risk, lower calorific value, and freezing point can be mitigated by manufacturers conducting annual quality evaluations through state-level coordinators as part of the biodiesel purchase policy.

2.5.1 What is biogas and compressed biogas?

The use of biogas and its purified, compressed form, Compressed Biogas (CBG), is a sustainable alternative to natural gas and supports India's transition to a gas-based economy. Biogas is generated through the anaerobic digestion of organic waste, including cattle dung and municipal solid waste, and then purified to remove CO_2 and H_2S. The result is CBG, which boasts key characteristics such as a calorific value similar to CNG and LPG (11,000 Kcal/kg to 12,500 Kcal/kg). Moreover, CBG offers environmental benefits, with 40% lower greenhouse gas emissions compared to LPG, making it an eco-friendly fuel choice. This transition to biogas-based energy will not significantly impact vehicle prices, as the government allows direct usage of CBG in CNG vehicles. The government aims to increase the proportion of gas in the energy mix to 15% by 2030, from the current 6.5%, to establish India as a gas-based economy.

2.5.2 Government initiatives to support adoption

Central and state government policies, backed by various incentives, are actively fostering the adoption of biogas as a renewable energy source across the country.

Supply-side Initiatives

The government has launched a range of initiatives to stimulate the adoption of biogas. The SATAT Scheme encourages entrepreneurs to establish Compressed Biogas (CBG) plants for the production and supply of automotive and industrial fuels, providing assurance for CBG off-take at fixed prices. The Agri Infrastructure Fund offers a 3% interest subvention for post-harvest infrastructure. State-specific incentives, exemplified by Uttar Pradesh's Bioenergy Policy 2022, allocate substantial funding for CBG production. Additionally, the Ministry of New and Renewable Energy (MNRE) provides financial assistance under the Waste to Energy Scheme, with higher incentives for special category states. The GOBAR-DHAN Scheme extends financial support for setting up model GOBARDHAN projects, and carbon credits can be earned by compressed biogas plants for reducing greenhouse gas emissions. Companies have also invested CSR funds in CBG projects to promote sustainability, exemplified by Mahindra Waste to Energy Solutions' endeavours in Maharashtra, supported by Mahindra & Mahindra.

Demand-side Initiatives

On the demand side, the government is introducing fuel mandates that will necessitate companies marketing natural gas and biogas to adopt a 5% CBG mandate. The Ministry of Road Transport and Highways has authorized CBG for use in motor vehicles, offering an alternative to Compressed Natural Gas (CNG). Awareness campaigns led by the Ministry of New and Renewable Energy aim to increase public understanding of clean energy like CBG. Moreover, the exemption of excise duty on GST paid on CBG when blended with compressed natural gas is expected to reduce fuel prices and encourage its adoption. These combined supply and demand initiatives form a cohesive strategy to boost the adoption of biogas and its purified compressed form, contributing to a greener and more sustainable energy future in India.

2.5.3 Expected benefits of adoption of compressed biogas

The widespread adoption of Compressed Biogas (CBG) in India will yield significant benefits, reducing greenhouse gas emissions and decreasing the country's reliance on liquefied natural gas (LNG) imports. Vehicles using CBG are estimated to emit 430 kg less equivalent CO_2 annually and produce 60 grams less CO_2 per kilometer per day compared to LPG. Achieving the CBG production target of 15 million metric tonnes per annum by 2024, as part of the SATAT initiative, will significantly boost India's self-sufficiency in energy, potentially saving up to US$ 8 billion. This transition is also expected to create around 75,000 direct job opportunities, particularly in rural areas, and stimulate local industries, offering numerous prospects for job creation and new business opportunities, thus contributing to a cleaner, greener, and more self-reliant energy landscape.

2.5.4 Biogas production and value chain

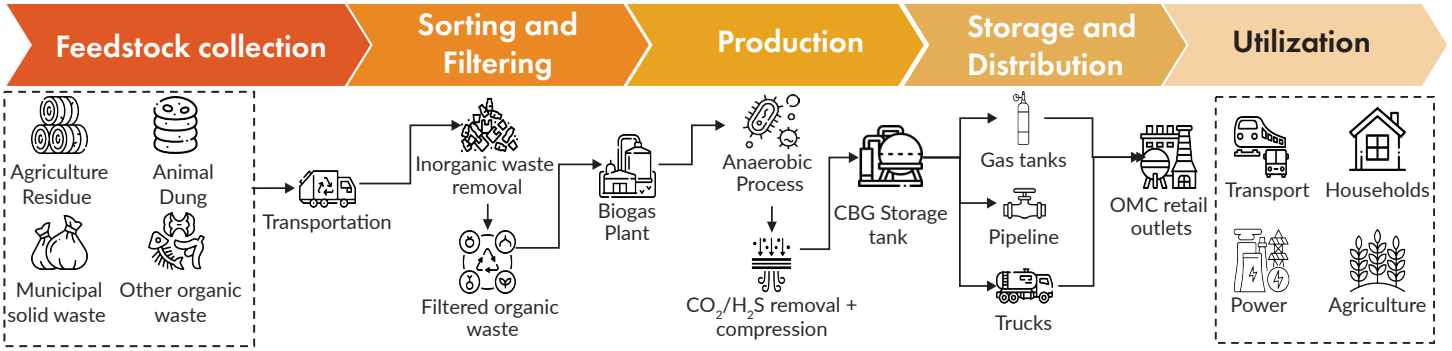
Biogas production in India involves various players, with feedstock supply and pre-processing primarily handled by unorganized participants. The feedstock collection is categorized into four segments, involving farmers and private companies. This setup offers benefits like additional income for farmers, the creation of job opportunities, decentralized energy access, and rural development, as illustrated in Exhibit 2.11.

The sorting and filtering stages come in various scales, including small-scale plants for domestic use, community-based systems serving entire communities, and industrial plants catering to commercial needs, often involving private investments and bank funding.

Within the production phase, various processes are employed for H_2S and CO_2 removal, including biological fixation, iron chloride dosing, water scrubbing, activated carbons, iron hydroxide, sodium hydroxide, pressure swing adsorption, water scrubbing, and membrane separation.

Exhibit 2.11

Multiple players exist in the production of biogas; feedstock supply & pre-processing is dominated by unorganized players



- Biogas producers are majorly segregated into 4 different segments based on the type of feedstock
- **Stakeholders:**
  - Farmers
  - Private companies
- **Opportunity**
  - Extra source of income to farmers
  - New job opportunities
  - Decentralized energy access

The scale of operations:

- Small scale plants: For domestic consumption of single families to fulfil their cooking needs
- Community-based: provides enough energy to meet the needs of the entire community
- Industrial plants: Established for commercial use and often involve private investments with bank funding

H_2S removal processes

- Biological Fixation
- Iron chloride dosing
- Water scrubbing
- Activated Carbons
- Iron Hydroxide
- Sodium Hydroxide

CO_2 removal processes

- Pressure swing adsorption
- Water scrubbing
- Membrane Separation
- Mono-ethylamine system

- **Trucks:** Used for smaller volumes for local distribution & longer journeys
- **Pipelines:** Another way to move CBG over longer distances
- **Gas Tanks:** For local use of CBG

- **Transportation:** Used as fuel in light-duty vehicles, buses, trucks, trains, and potentially shipping and aircraft
- **Households:** Can replace LPG as a fuel used for cooking. Can also be used for heating purposes
- **Power:** Can be used in power generation via gas turbines
- **Agriculture:** The fermented organic manure(FOM) generated during the process can be used for agricultural purpose

Players

Feedstock producers	Feedstock pre-processing	Compressed biogas producers	Technology providers (Machines/ equipment)	Oil marketing companies (OMC)
Abellon, CLENERGEN	Abellon, PRESPL, Eco BioFuel, MAA JOGAINIYA TRADING	Verbio, FARMGAS, NobleExchange, UZZALA, AgroGaz, GREEN ELEPHANT, VEOLIA, SPECTRUM, NEXGEN ENERGIA LTD., SAVPL, EVER ENVIRO, CARBON MASTERS, Solika Energy, Biofics, praj	ARYA, OVN Bioenergy Pvt Ltd, GGE, Evergreen Power Limited	IndianOil, Bharat Petroleum, GAIL (India) Limited, INDRAPRASTHA GAS LIMITED, HP

Note(s): *CBG- Compressed BioGas
Source(s): Gobardhan, MoPNG, Government reports, Press releases, Praxis analysis

For storage and distribution, trucks are utilized for local transport, pipelines offer long-distance movement, and gas tanks are employed for local use.

Biogas has diverse applications, serving as a fuel for various modes of transportation, including light-duty vehicles, buses, trucks, trains, and potentially ships and aircraft. It can replace LPG in households for cooking and heating, is suitable for power generation via gas turbines, and provides organic manure for agricultural purposes. Underscoring the potential and versatility of biogas across the entire value chain in India.

2.5.5 Demand and supply analysis of CBG

India boasts significant potential in the Compressed Biogas (CBG) sector, with an estimated capacity of approximately 62 million metric tons per annum (MMTPA). However, the current realization of this potential remains remarkably low, at less than 1%. Unlocking the full potential of CBG could potentially replace up to 70% of India's current consumption of LPG (liquefied petroleum gas) and natural gas, making it a crucial element in the country's energy landscape.

Over the past few years, the consumption of LPG and natural gas in India has experienced steady growth, with a Compound Annual Growth Rate (CAGR) of approximately 6%. Natural gas imports have also grown at a rate of 5% from FY19 to FY23, indicating the increasing demand for these fuels.

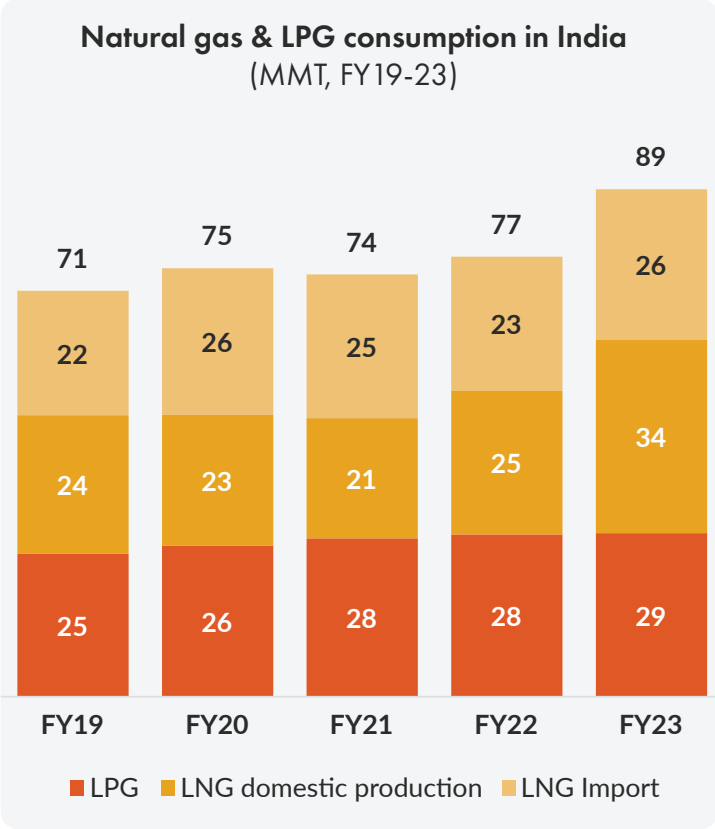
To put this into perspective, in FY23, India's LPG consumption reached 29 million metric tons, with domestic production of liquefied natural gas (LNG) at 34 million metric tons and LNG imports at 26 million metric tons, making the total consumption of LPG and natural gas around 89 million metric tons in the country, as illustrated in Exhibit 2.12.

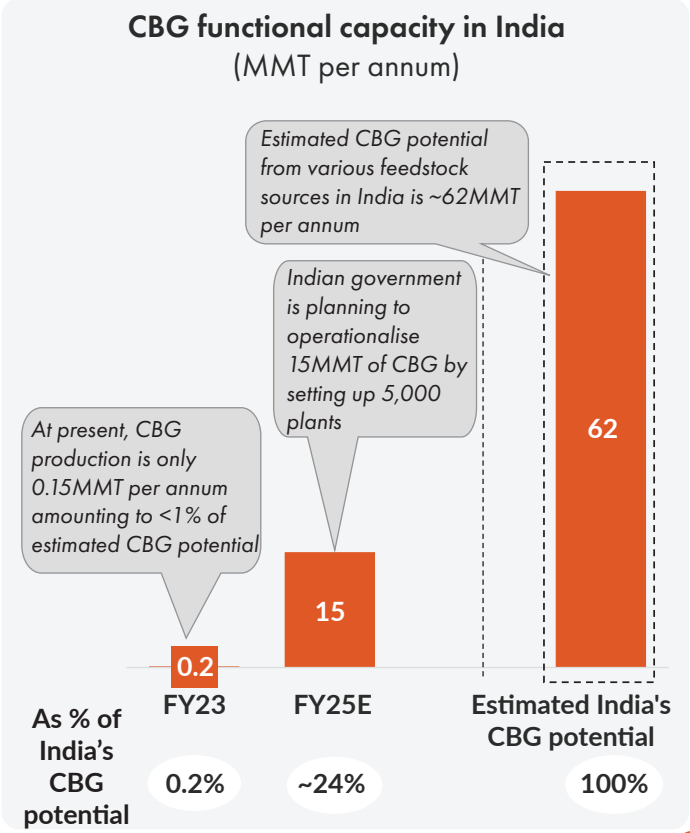
Presently, India is utilizing less than 1% of its estimated CBG potential, which amounts to approximately 0.15 million metric tons per annum.

However, the Indian government has ambitious plans to significantly scale up CBG production. By FY25, it aims to operationalize 15 million metric tons of CBG through the establishment of 5,000 CBG plants, potentially reaching around 24% of the country's CBG potential. India's estimated potential for CBG is 62 million metric tonnes and realizing this potential will be a transformative milestone in India's journey towards a sustainable and cleaner future.

Exhibit 2.12

India's estimated CBG potential is ~62MMTPA of which <1% is realized; 100% realization has potential to replace ~70% of India's current LPG & natural gas consumption





Note(s): *CBG- Compressed Biogas
Source(s): Gobardhan, Ministry of New and Renewable energy, Praxis analysis

2.5.6 Impact across stakeholders

The transition to Compressed Biogas (CBG) in India holds the potential for significant environmental and economic benefits.

a) **Environmental Benefits:** CBG adoption reduces vehicular emissions, including carbon monoxide and hydrocarbons. It substantially cuts greenhouse gas emissions, with each CBG-fuelled vehicle reducing GHG emissions by 430 kg equivalent CO_2 per vehicle. Additionally, CBG is considered safer than CNG and LPG, dispersing into the air in case of spills, minimizing safety hazards.

b) **Farmers:** Transitioning to CBG provides income diversification for farmers through the sale of agricultural residue and waste, fostering job creation and rural energy security.

c) **Biogas plant producers:** Producers can tap into new revenue streams by participating in carbon credit trading, thereby promoting clean and renewable energy.

d) **Automakers and OEMs:** Manufacturers can expand their product portfolios by introducing bio-CNG vehicles with no engine modifications required if CBG meets IS 16087-2016 standards.

e) **Oil marketing companies:** While the growing demand for CBG presents expanded opportunities, the introduction of a 5% CBG mandate may add complexity and increased costs to the supply chain. However, CBG is easily sourced and can be directly transported into CNG pipelines, facilitating its adoption.

f) **Government and regulatory agencies:** CBG offers an effective means for governments to meet emission reduction targets and spur the growth of a sustainable energy industry. Achieving SATAT goals can reduce LNG imports by 55%, alleviating the import burden and enhancing energy security. However, there are certain challenges that must be overcome for smoother adoption.

2.5.7 Challenges in adoption and mitigation measures

a) **Scalability and maintenance:** Sourcing vast feedstock quantities for large plants (>100TPD) is a challenge due to storage costs. Common issues like pipe clogging and scum formation lead to production disruptions. Mitigation measures include regular maintenance, spare parts inventory, and contingency plans.

b) **CO_2 separation:** Separating CO_2 is costly, and complex technologies can result in methane losses. Mitigation involves advanced technologies, operator training, and regular maintenance.

c) **Efficiency maintenance:** Feedstock choice affects gas yield thus technology selection is vital to prevent scum formation. Risk mitigation involves co-digestion and gas upgradation.

d) **Pre-treatment of raw biomass:** Organic and inorganic waste segregation challenges need attention. Mitigation strategies include size reduction for higher yield, homogenization, moisture control, and quality checks.

e) **Biomass cost:** Feedstock cost volatility impacts CBG economics. Mitigation includes vertical integration, long-term contracts, and diversification.

f) **Plant cost:** High equipment costs due to a lack of economies of scale. Collaboration with other biogas producers can help.

g) **Feedstock sourcing:** Accessibility and affordability challenges require procurement from multiple sources and partnerships.

h) **Transport:** Slow technology adoption and poor connectivity can be managed by investing in road construction and maintenance.

i) **Storage:** Challenges in feedstock and CBG storage can be mitigated by following proper SOPs and emphasizing FOM marketing.

3.1 Types of hydrogen

Hydrogen production has evolved over the years and is currently obtained through three main processes, namely grey, blue and green hydrogen.

Grey is the oldest and easiest method of obtaining hydrogen, where natural gas / coal is used as a feedstock which is reacted with steam and water to generate hydrogen. While the process involved in generation is relatively straightforward, it generates significant CO_2 emissions, making it a contributor to greenhouse gas emissions.

Blue hydrogen involves the same base method as grey, the key difference here is that carbon capture and storage (CCS) technology is used to capture and store a significant portion (usually around 90%) of the CO_2 emissions produced during the process. Minimizing the impact on the environment.

Green hydrogen is the latest innovation in this space which generates zero CO_2 emissions. Here hydrogen is produced through the electrolysis of water, and the electricity used for the process is obtained through renewable sources.

3.2 Fuel cells electric vehicles (FCEV)

FCEVs are a type of electric vehicle that uses hydrogen gas (Green hydrogen) to generate electricity and power the electric engine.

Unlike traditional electric vehicles, FCEV consists of an in-built powerplant that converts hydrogen into electricity. Fuel cells within the FCEV use the process of reverse electrolysis where hydrogen reacts with oxygen to produce electrical energy, water and heat. This energy is used to power the engine / motor which helps run the vehicle. Meanwhile, any additional energy generated is stored in batteries.

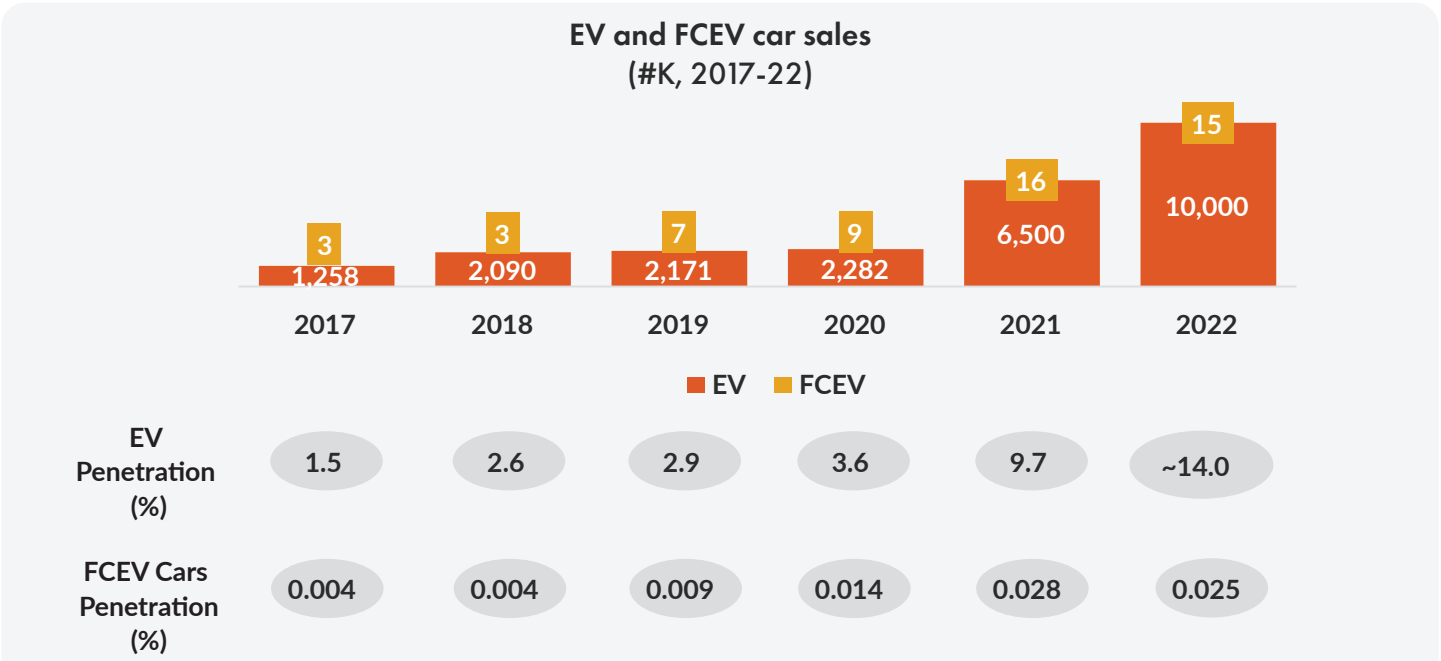
3.3 Adoption of FCEV

Global adoption of the FCEV market has been rising over the past 5 years, although overall market penetration has been lower compared to traditional electric vehicles as illustrated in exhibit 3.1.

Interest in FCEVs has surged recently as several major original equipment manufacturers (OEMs) such as Honda, Toyota, and BMW have committed to manufacture FCEVs.

Exhibit 3.1

Global penetration of hydrogen-fuelled vehicles is ~0.02%, while EVs have a penetration of ~14% in 4W passenger cars in 2022.

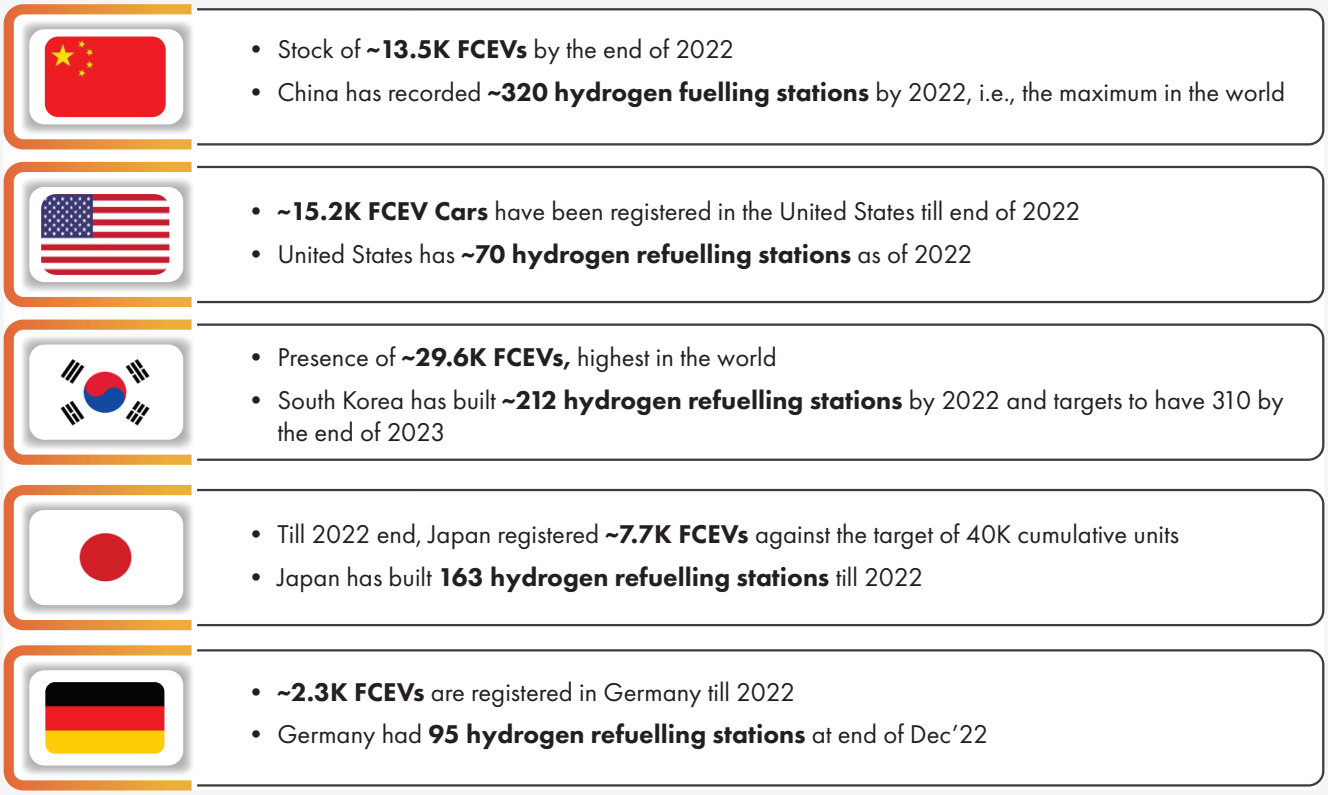


Source(s): IEA, Industry reports, Secondary research, Praxis analysis

China, USA, South Korea, Japan and Germany are leading the global FCEV market (Exhibit 3.2). Significant government investments and broader efforts to transition to sustainable methods of transportation have been the drivers for the adoption of FCEV in these countries.

Exhibit 3.2

FCEV adoption in key geographies of China, USA, South Korea, Japan and Germany till the end of 2022



Source(s): IEA, Industry reports, Secondary research, Praxis analysis

3.4 Government and private sector initiatives

India's hydrogen vehicle adoption is currently at a nascent stage, but it is expected to gain momentum through government and private initiatives.

The government and Ministry of Petroleum and Natural Gas (MoPNG) has undertaken several initiatives to develop hydrogen as a fuel, which include:

a) **National Hydrogen Mission:** The government launched the National Hydrogen Mission (NHM) in 2021 to develop hydrogen as a transportation fuel

b) **Pilot project:** MoPNG is running pilot projects on the use of hydrogen:

- Grey hydrogen, where hydrogen is blended with CNG to the extent of 18% for use as a transportation fuel
- Green hydrogen, where hydrogen is used as a transportation fuel and an industrial input to refineries

c) **Hydrogen highways:** Government has rolled out plans to develop hydrogen highways, where green hydrogen production projects, distribution infrastructure and refueling stations will be built. This will enable Hydrogen fuelled inter-state buses and commercial vehicles to ply these routes.

d) **Deployment of FCEV buses and trucks:** Under the green hydrogen mission, FCEV buses and trucks will be deployed in a phased manner on pilot basis. To solve for high initial capital cost, financial assistance will also be provided.

Private players have also entered the green hydrogen space, propelling it forward through a series of initiatives and projects, such as:

a) Toyota, in collaboration with International Centre for Automotive Technology (iCAT) has started a pilot project to evaluate the performance of Toyota Mirai, first FCEV in India on Indian roads and climatic conditions.

b) Cummins and Tata Motors have set up a new business entity called TCPL Green Energy Solutions Private Limited, to develop and manufacture sustainable technology products including hydrogen-powered internal combustion engines and fuel cell electric systems.

c) KPIT-CSIR developed the first hydrogen fuel cell bus in India, which was launched in August 2022.

d) Reliance Industries Limited and Ashok Leyland showcased India's first hydrogen internal combustion engine powered heavy-duty truck early this year.

3.5 Opportunities and challenges for FCEV adoption

Abundance of hydrogen and higher range vehicles offer promising FCEV adoption, but extraction, initial costs, and limited infrastructure pose significant roads towards the adoption, as illustrated in Exhibit 3.3.

Exhibit 3.3

Opportunities and challenges towards the adoption of hydrogen fuel cell electric vehicles across the globe

Tailwinds / Opportunities for the adoption of FCEVs		Headwinds / Challenges in adoption of FCEVs	
Dependent on abundant resource	• Hydrogen is **abundant, found in water,** hydrocarbons, and organic matter • **Excess solar energy** can be used for **hydrogen production** via **electrolysis**	**Challenging extraction**	• Hydrogen extraction is **energy-intensive,** relying on fossil fuel isolation or water electrolysis
Higher range vehicles	• **FCEVs** can run **300 miles** and refuel in 10 minutes, while **EVs** have a **200-mile range** and take 45 minutes to fast/DC charge	**High upfront cost**	• Hyundai Kona EV starts at **EUR 34.6K** in Europe, while Hyundai Nexo FCEV costs around **EUR 69K,** making **FCEVs** significantly **more expensive** than **EVs**
Lower carbon footprint	• **FCEVs** produce only **water** as a by-product, emitting no harmful emissions	**Higher refuelling costs**	• FCEV **refuelling costs** is US$ 0.14/km **higher** than EV costs of US$ 0.03/km
Alternative for lithium	• In **2021**, global lithium production was **91K MT,** with reserves of **~20M MT,** with **single car** containing **8kg** of Li-ion battery • Lithium **shortage** is anticipated by **2030**	**Limited charging infrastructure**	• **Hydrogen charging** infrastructure is **limited compared to EVs**
Quick refuelling	• FCEVs offer gas car-like **refueling speed** and **maintain range** in cold weather, **unlike EVs**	**Technology & safety issues**	• Fuel **cell systems** are **less durable** than **internal combustion** engines • Fuel cells **lose stability** and efficiency **over time** due to corrosion from small particles and carbon • Hydrogen's **high flammability** raises **safety concerns**

Source(s): US geological survey, Industry reports, Secondary research, Praxis analysis

Importance: Low | Medium | High | Very high

3.6 Recommendations for future adoption

FCEV represents the future of clean mobility. It is crucial for India to ensure a sufficient supply of carbon-free hydrogen. In our opinion, the following recommendations would propel the country towards this goal. (Illustrated in detail in Exhibit 3.4).

a) Develop clear strategies and roadmaps for future adoption.

b) Provide incentives and subsidies to enhance the project economics during early adoption stages.

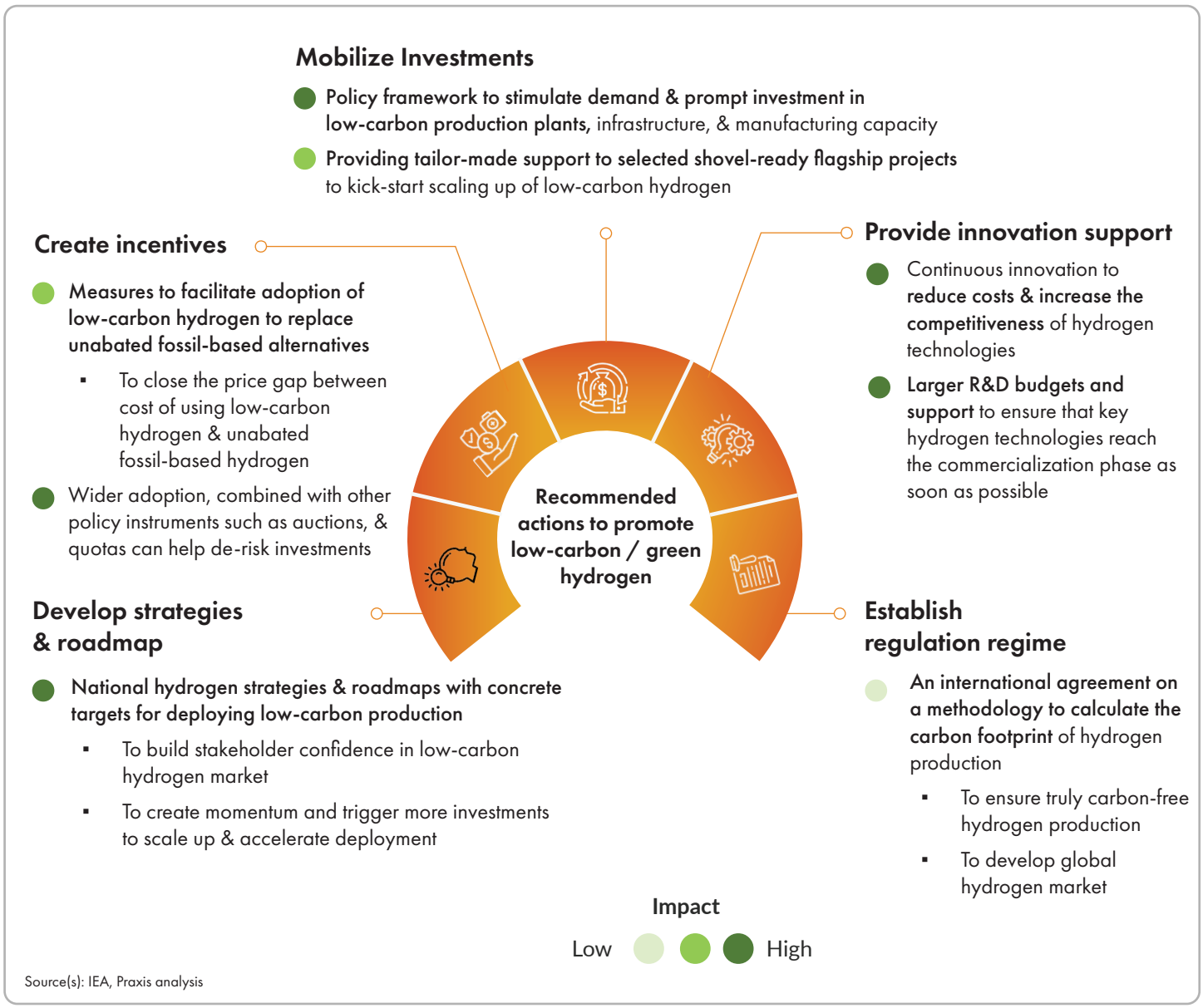
c) Mobilize investment to support flagship green hydrogen projects.

d) Provide support for research and development to ensure quick commercialization of technologies.

e) Establish a strong regulatory framework to ensure global standards and methodologies to calculate carbon footprint of various technologies.

Exhibit 3.4

Our recommended actions to promote the adoption of low carbon / green hydrogen in India



Source(s): IEA, Praxis analysis

04 Conclusion

Considering the escalating global challenges posed by climate change and India's significant contribution to greenhouse gas emissions, there is a pressing need to shift to sustainable and eco-friendly energy alternatives to emerge.

The adoption of biofuels as an environmentally responsible and strategically sound choice has gained prominence, aligning India with global leaders in this domain. Biofuels, including ethanol, biodiesel, and biogas, have clear potential to replace conventional fossil fuels, primarily in the transportation sector. They present a practical solution to reduce emissions, enhance energy security, and reduce dependence on imported crude oil.

Globally, India is part of the growing demand for biofuels, with a 3% market share, driven by government policies promoting ethanol and biodiesel blends. Government policies supporting biofuel adoption, akin to those in the USA and Brazil, provide a clear roadmap for India's transition. Collaborating with these biofuel pioneers and steadfastly pursuing its goals will be essential for India as it charts a course toward a more sustainable and resilient energy future.

India reached a significant milestone in biofuel usage in November 2022 by achieving the E10 fuel target. This accomplishment has led to a 32 million-metric-ton reduction in greenhouse gas emissions over the past eight years. It has also resulted in savings exceeding INR 70,000 crores in import bills and an increase of more than INR 17,000 crores in farmers' income.

The initiative by the Government of India (GoI) to transition from E10 to E20 by 2025 in fuel and use B5 by 2030 holds significant promise and potential for a cleaner, more sustainable, and economically beneficial energy future. The adoption of E20 and B5 is expected to result in substantial reductions in greenhouse gas emissions, providing a cleaner environment. Agricultural stakeholders stand to gain from diversified revenue streams by supplying agricultural waste as feedstock for ethanol production, while entrepreneurs have opportunities to invest in and establish ethanol/biodiesel manufacturing facilities. Government of India is actively taking measures to ensure a smooth transition to E20 by 2025 and B5 by 2030, creating a greener and more sustainable energy landscape in India. The annual savings from the implementation of E20 alone are estimated to be INR 30,000 crores.

Furthermore, India has made substantial progress in the field of biogas production. The government's ambitious target of increasing the share of biogas in the energy mix from the current 6.5% to 15% by 2030 constitutes a monumental step towards not only reducing greenhouse gas emissions and developing a more diversified and sustainable energy portfolio but also has the potential to create more than 5,000 jobs.

Apart from biofuels, India is starting its journey in hydrogen production and using it for electric vehicles, there's a need for clear plans, support, investments, research, and robust regulatory framework to ensure the successful and sustainable adoption of FCEVs.

The strategic adoption and effective implementation of biofuel and green hydrogen programs are integral to realizing India's sustainability and energy security objectives. The nations commitment to achieve an E20 blend by 2025, and further solidify its position by successfully implementing a mandate for B5 blend in biodiesel and incorporating a 15% share of biogas in the overall energy matrix by 2030, positions India alongside global leaders. These concrete steps not only underscore India's resolute determination but also propel the country significantly closer to its ambitious net-zero emissions goal.

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