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प्राकृतिक गैस मंत्रालय
MINISTRY OF
PETROLEUM AND NATURAL GAS

सत्यमेव जयते

PPAC Journal

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Writers from

**OPEC, IEA,S&P Global,IRADe,IEEFA,
BEE,CHT, Invest India,MCX, TERI and more.**

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Editorial

Dear Readers

Energy scene is changing rapidly. This has happened in past too when world has shifted gears from one form of energy to another. However, reason of transition this time is different, the climate change. That makes it imperative on to stakeholders to communicate the need and pathways to each other including the consumer.

Petroleum Planning & Analysis Cell (PPAC), an attached office of the Ministry of Petroleum & Natural Gas (MoPNG) is a trusted organisation which disseminates data and analysis for its stakeholders and public. It releases various data reckoners and reports on regular frequency through its website. Taking its objective forward, PPAC has now decided to have a biannual journal of articles on various facets of Energy Transition.

We are happy that first issue of the PPAC Journal is now before you. This issue has articles from eminent energy experts and organisations on various aspects on the subjects ranging from India`s role as powerhouse of growth to biofuels in energy transition.

This issue is coming after COP28 which started with announcement of loss and damage fund that will help developing countries that are vulnerable to the consequences of climate change. The conference ended with another big call to phase out of all fossil fuels.

We fully understand that this being first issue may not be very smooth but that is true about climate change and energy transition too. We consider this initiative as small step towards sharing knowledge.

We are thankful to overwhelming response from the experts. We could not include some of the articles in view of space constraints. We will certainly strive to relook at them in our next issue. We acknowledge the sincere support of Executive Director-PRCC HPCL for assisting PPAC in bringing this issue of the journal in the form and shape it has come out. We also acknowledge Mr Sandeep Gawde for designing this issue of the journal.

We would like to add that Views expressed in the articles are those of the writers in their personal capacities and PPAC has only provided a platform for knowledge sharing. PPAC/MoPNG will not be responsible for any errors, omissions, discrepancies, and disputes arising out of these articles.

Suggestions and Feedback from the readers are invited for improvement of the PPAC Journal. We also invite articles for our next issue.

Warm Regards,

Dr Pankaj Sharma | Additional Director, PPAC
Editor

Message from Director General

Petroleum Planning & Analysis Cell (PPAC), an attached office of the Ministry of Petroleum & Natural Gas (MoPNG), Government of India, collects, compiles, analysis and disseminate data on the Oil and Gas Sector. The data is collected from Public Sector Oil Companies, Government Agencies and Private Companies. Over the years, PPAC has set a benchmark and expanded its coverage to fill the gap in the data requirements of the Government of India in Oil and Gas Sector. The endeavour of PPAC is to strengthen the Oil and Gas data infrastructure of the country.

PPAC publishes various periodical reports, which are comprehensive databank for key Oil & Gas industry of the country. Now we come up with its own journal, which provides a platform for various domain experts to share their knowledge with stakeholders and the best practices in the sector.

The first edition of PPAC Journal comes when India has shown a path of cooperation by spearheading Global Biofuel Alliance during G20 Leaders' Summit under her presidency. This is true to the motto of 'One earth, One family, One future' in tradition of our ethos 'Vasudhaiva Kutumbakam'. India has also shown its imprint during COP28 and has offered to host COP30.

It is quite evident in the inaugural edition of the PPAC Journal, which is being released during India Energy Week 2024 at Goa, that India has significant role in the energy transition. I am confident that the journal will give insight on various domains pertaining to oil and gas sector.

I appreciate the support and contribution of all who have helped us to publish the journal. I would like to place on record my appreciation to the editorial board at PPAC for their diligent efforts to bring out this edition in a timely manner.

P. Manoj Kumar
Director General
Petroleum Planning & Analysis Cell (PPAC)
(Ministry of Petroleum & Natural Gas)

01

India: a major powerhouse of future energy and oil demand growth

OPEC Secretariat,
Vienna, Austria

Driven primarily by favourable demographics, rapidly progressing urbanization and economic growth of more than 6% p.a. on average in the period to 2045, India is set to be a major source of incremental energy and oil demand for decades to come. Indeed, overall primary energy demand in India is projected to almost double between 2022 and 2045, reaching 38.5 million barrels of oil equivalent per day (mboe/d) in 2045 compared to 19.2 mboe/d observed in 2022. While demand for all energy sources will increase during this period, oil will account for the largest part of the growth. In volume terms, oil demand in India is projected to more than double between 2022 and 2045, from 5.1 mb/d in 2022 to 11.7 mb/d in 2045.[1]

Demographic and economic prospects

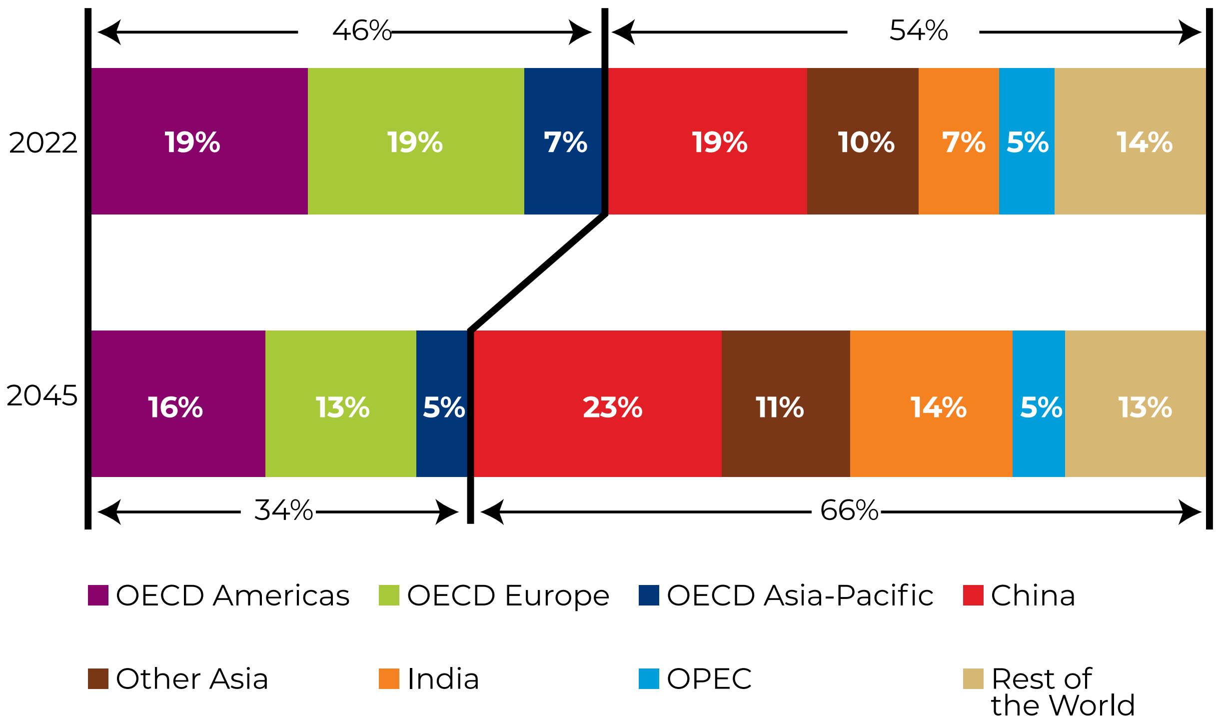
Latest estimates from the UN Department of Economics and Social Affairs (UNDESA) show that India reached a population of 1.43 billion during 2023, surpassing that of mainland China. Moreover, projections made by UNDESA show that India's population will continue growing over the next two decades and reach 1.62 billion by 2045. Besides this significant increase in its population, around half of India's population is currently below the age of 25. As a result, the country's working-age population is expected to expand to around 1.1 billion by 2045.

Another important aspect of India's demographics that will have a significant impact on future energy and oil demand is the urbanization rate. Despite the fact that India is home to several of the most populous cities in the world, its current urbanization rate is only around 34%. This is much lower compared to developed countries, as well as many developing countries. With many policy interventions in recent years, such as the 'Smart Cities Mission' initiative, the construction of affordable rental housing complexes and adapting rapid transport metro systems in larger cities, India's urbanization rate is set to increase to around 50% at the end of the forecast period. In turn, this will support demand growth for modern energy sources, including oil.

This favourable demographic growth will drive India's economic expansion too. Its GDP is projected to grow by 6.1% p.a. on average between 2022 and 2045, remaining robust even towards the end of the forecast period. As a result, India' GDP is expected to nearly quadruple, adding about $29 trillion (on a 2017 PPP basis) to its economy over the forecast period. By comparison, an addition of $35 trillion and $28 trillion of

Figure 1

Distribution of the global economy, 2022 and 2045



Source: OPEC World Oil Outlook, 2023

GDP is anticipated for China and the OECD during the same period, respectively. In combination with the relatively high GDP growth in other non-OECD regions, this will lead to a significant shift in the regional distribution of GDP over the forecast period, as presented in Figure 1. India's share of global GDP is set to rise from around 7% in 2022 to 14% in 2045. China and India, combined, are expected to increase their share of global GDP from 26% in 2022 to 37% in 2045. In contrast, the share of OECD countries will decline from 46% to 34%.

Primary energy demand

India's primary energy demand is projected to almost double in the outlook period, reaching 38.5 mboe/d in 2045, driven by increasing population, rising urbanization, an expanding middle class and economic development. India alone accounts for almost 28% of non-OECD primary energy demand growth to 2045. While demand for all energy sources will increase during this period, oil will account for the largest part of the growth as India's demand for oil products will more than double from 5.1 mboe/d in 2022 to 11.6 mboe/d in 2045.

Table 1

India primary energy demand by fuel type, 2022-2045

	Levels (mboe/d)						Growth (mboe/d)	Growth (% p.a.)	Fuel share (%)	
	2022	2025	2030	2035	2040	2045	2022-2045	2022-2045	2022	2045
Oil	5.1	5.8	7.3	8.7	10.1	11.6	6.5	3.6	26.7	30.1
Coal	8.3	9.0	10.4	11.6	12.5	12.8	4.5	1.9	43.3	33.2
Gas	1.0	1.2	1.7	2.2	3.0	4.1	3.1	6.2	5.3	10.6
Nuclear	0.3	0.3	0.5	0.7	1.0	1.3	1.0	7.1	1.4	3.3
Hydra	0.3	0.3	0.4	0.5	0.6	0.6	0.3	3.3	1.6	1.7
Biomass	3.9	4.0	4.1	4.2	4.2	4.2	0.3	0.4	20.2	10.9
Other renewables	0.3	0.6	1.1	1.8	2.7	3.9	3.6	11.5	1.7	10.1
Total	**19.2**	**21.3**	**25.4**	**29.7**	**34.1**	**38.5**	**19.3**	**3.1**	**100.0**	**100.0**

Source: OPEC World Oil Outlook, 2023

In line with expanding electricity demand, India's coal demand is expected to increase, especially in the first part of the outlook period. From 8.3 mboe/d in 2022, coal demand is projected to rise to 11.6 mboe/d in 2035, and further, albeit at a slower pace, to 12.8 mboe/d in 2045. The reason for coal's slowing pace is the faster deployment of other energy resources, especially gas, nuclear and other renewables. The contribution of other renewables, mainly wind and solar energy, is projected to increase from 0.3 mboe/d in 2022 to almost 4 mboe/d in 2045. Consequently, the share of other renewables is set to increase to around 10.1% by 2045 from below 2% currently. The Indian government is supporting the expansion of renewables, including the expansion of transmission and distribution networks. The official target is to reach 500 GW capacity of renewables by 2030, which is an ambitious target, given the current renewable capacity of around 160 GW.

Natural gas is also expected to expand strongly in the medium- and long-term. Increasing the share of gas in the mix will help to reduce coal usage, curb CO2 emissions and support the deployment of intermittent renewables such as wind and solar. Furthermore, the government supports the gasification of the country (City Gas Distribution project), which aims to reduce the usage of traditional cooking fuels in the residential sector, such as wood charcoal, but will also partly reduce the use of LPG and kerosene. Although the government has a target of 15% for gas in the energy mix by 2030, the Reference Case sees a share of around 10.5% by 2045.

Nuclear power is likely to more than triple in the forecast period, from 0.3 mboe/d to 1.3 mboe/d in 2045. Around 6 GW of nuclear capacity is under construction, which, once online, would almost double the country's current installed capacity. Finally, hydropower and biomass demand are each expected to increase by 0.3 mboe/d over the outlook period. The country is also set to reduce the traditional use of biomass, which will be more than offset by its modern use and the transformation into bio liquids and biogas.

Liquids demand [2]

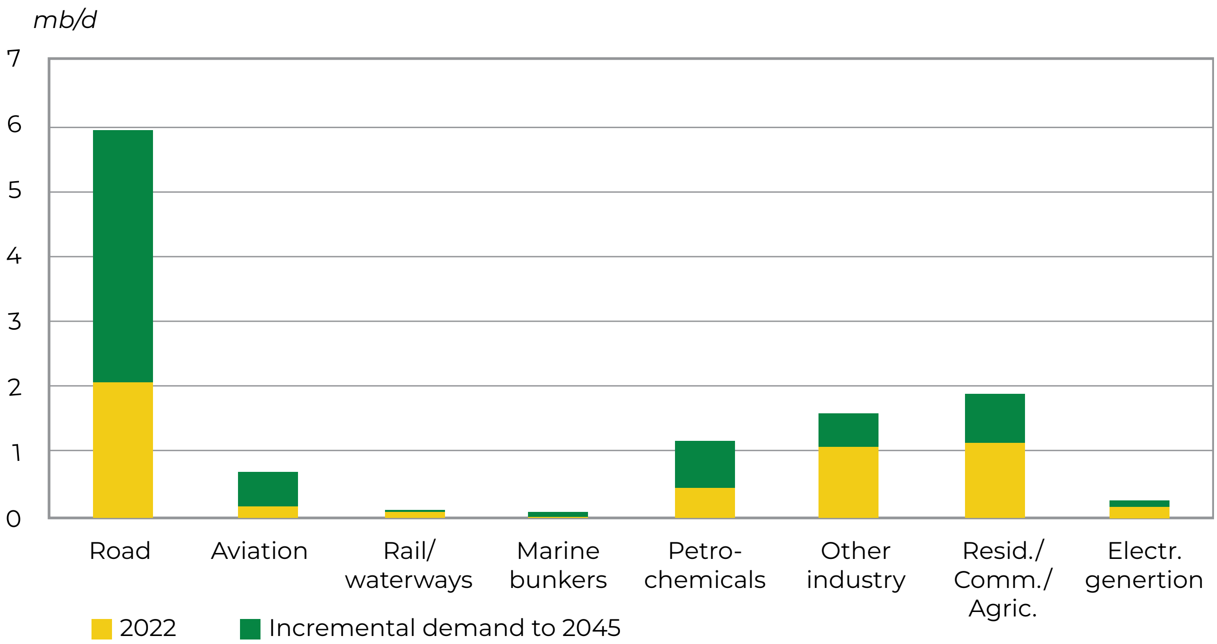
The 2023 edition of OPEC's WOO projected global oil demand would increase by 16.4 mb/d between 2022 and 2045, rising from 99.6 mb/d in 2022 to 116 mb/d in 2045. An important feature of this outlook are the divergent regional oil demand pathways of OECD and non-OECD countries. Indeed, with the exception of the initial few years of the forecast period when OECD demand is set to expand, the long-term prospects for this region is a continued demand decline to below 37 mb/d by 2045. This will be 9.3 mb/d lower than the observed demand in 2022.

In contrast, non-OECD oil demand is expected to increase by 25.7 mb/d between 2022 and 2045. Rising population and urbanization, the strong expansion of the middle-class, robust economic growth potential, the shift from traditional use of biomass to cleaner oil products, strong vehicle fleet growth, including commercial vehicles with a higher share of heavy-duty vehicles, and agriculture sector shifts will all result in strong demand growth in this region. Moreover, these factors also well describe future developments in India, the largest contributor to the non-OECD demand increase, as this country will add 6.6 mb/d to its oil demand during the forecast period, reaching 11.7 mb/d by 2045.

As presented in Figure 2, by far the largest expected demand growth in India is for transport fuels. Strong economic growth will drive demand for freight transport, leading to incremental demand for diesel in the road transportation sector. It will also lead to a fast expansion of the middle class which, in combination with urbanization and improved road infrastructure, will result in a more than quadrupling of the number of passenger vehicles between 2022 and 2045. The size of the passenger vehicle fleet in India is set to expand from around 46 million in 2022 to almost 200 million in 2045 (excluding two- and three-wheelers). In contrast to China and OECD Europe, the penetration of EVs will likely remain subdued in India, with the large majority of vehicles using internal combustion engines (ICE). This is forecast to increase India's gasoline demand by around 1.6 mb/d over the forecast period, and further support diesel demand in road transportation.

Figure 2

Oil demand by sector in India, 2022 and 2045



Source: OPEC World Oil Outlook, 2023

Significant demand growth is also projected in other sectors, especially the petrochemical and residential sectors. Oil demand in the petrochemicals sector is set to expand by 4.3% p.a. on average between 2022 and 2045, driven by demand for a variety of petrochemical products. This is on the back of growing construction and industrial production, an expanding agriculture sector and demand for plastics. This also manifests itself in the list of petrochemical projects that are expected to be constructed and become operational over the next few years, as the country is forecast to account for around one third of new projects in Asia. As a result, India's oil demand in this sector is set to increase by 0.3 mb/d already by 2030. It is then anticipated to further extend this incremental demand to 0.7 mb/d by 2045, compared to 2022.

A similar level of incremental demand, 0.8 mb/d over the forecast period, is projected in the combined residential, commercial and agricultural sectors, expanding from

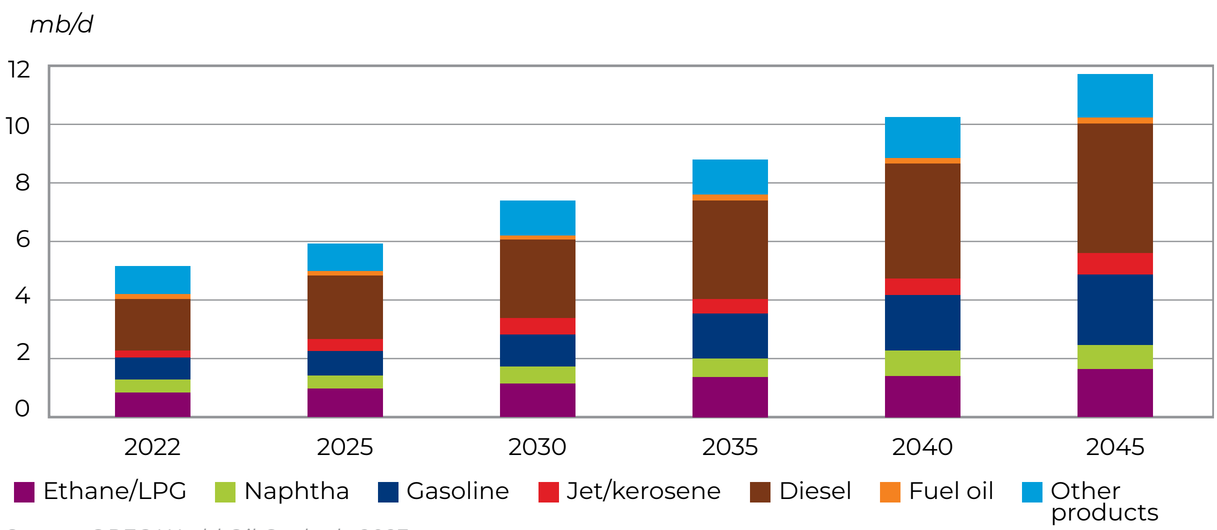
1.1 mb/d in 2022 to 1.9 mb/d in 2045. Reflecting the strong population growth and increases in the urbanization rate, there remains the potential for additional oil demand in this sector. However, part of this potential will likely be met by other energy sources, such as electricity and natural gas. In particular, residential oil demand will face competition in areas where natural gas access is improved as part of the City Gas Distribution programme.

The most dynamic changes are expected in the aviation sector. Oil demand in this sector is projected to expand by more than 6% p.a. on average during the forecast period. The current demand base is relatively low, as observed oil demand for aviation was below 0.2 mb/d in 2022. This, however, will gradually change on the back of governmental initiatives that support the construction of new regional airports and provide schemes to make air transport affordable to common citizens, such as the UDAN scheme and the Regional Connectivity Scheme (RCS). Alongside the expected growth of the middle class, both domestic and international air traffic will increase significantly over the forecast period. Accordingly, India's oil demand in this sector is set to increase to 0.7 mb/d in 2045.

Figure 3 translates these sectoral trends into demand for specific refined products. India's current oil demand composition is characterized by a relatively high share of diesel/gasoil, which accounts for around 35% of total demand. In future, the share of diesel/gasoil is set to expand to 38%, mainly on the back of growing freight transport and industrial production. Some demand growth for this product will also come from the petrochemical industry, as well as the commercial and agriculture sectors. Therefore, the projected diesel demand level for India in 2045 is 4.4 mb/d.

Figure 3

Oil demand in India by product, 2022–2045



Source: OPEC World Oil Outlook, 2023

As discussed earlier, India's incremental gasoline demand will result from the growing number of passenger vehicles, with the range of the increase around 1.6 mb/d between 2022 and 2045. In a similar way, jet kerosene demand growth, which is anticipated to increase by 0.6 mb/d, is directly linked to aviation sector developments.

Significant incremental demand is also projected for ethane/LPG. Combined demand for these two products is set to increase by 0.7 mb/d over the forecast period. The larger part of this increase relates to LPG demand in the residential sector. This will be supported by ethane growth in the petrochemical sector. However, demand in this sector in India is dominated by naphtha. Therefore, naphtha demand is expected to increase by 0.5 mb/d, from 0.3 mb/d in 2022 to 0.8 mb/d in 2045.

Another specific of the Indian oil market is the relatively high demand for the group of 'other products', such as bitumen, pet coke, lubes and waxes. Most of these products are used to expand the road network, as refinery fuels and to produce energy-intensive goods such as cement, aluminium and steel. Since all these sectors are set to expand in India, related product demand is also set to grow from 1 mb/d in 2022 to 1.5 mb/d in 2045.

The only refined product projected to remain in a narrow range of 0.1 mb/d to 0.2 mb/d during the entire forecast period is residual fuel oil. This is due to the fact that India has no major international bunkering hubs and given that the electricity sector is dominated by the use of coal, renewables and natural gas.

Conclusions

The sheer size of the Indian economy and its dynamic demographic prospects provide a sound basis for fast growing energy and oil demand in the decades to come. In fact, if measured in absolute terms, India is projected to be the single largest contributor to global incremental energy and oil demand. However, given its fast population growth, per capita energy consumption in India will remain below levels in developed countries and some developing countries. This fact underscores the even larger growth potential that exists in the country. Related to this is the scale of investments required to meet the growing energy demand. But, given recent progress made by the government and the private sector on energy-related investment, the country has a platform from which these can be attained.

References

1 *All analysis and projections included in this article are based on the 2023 edition of OPEC's World Oil Outlook (WOO).*

2 *Oil/liquids demand in this part of the article is expressed in volumetric units of million barrels per day (mb/d). Therefore, figures may differ from those presented under primary energy demand. Moreover, the definition of oil here includes all liquid fuels such as biofuels, coal-to-liquids (CTLs) and gas-to-liquids (GTLs) in addition to oil-based products.*

02

India's Energy Transition: More Energy, Fewer Emissions

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Introduction

Any path to global net-zero global emissions will have to travel through India due to the country's energy use, its projected demand growth and the commensurate increase in greenhouse gas emissions. India's development trajectory will also influence countries in the Global South that are trying to provide secure, reliable and affordable energy to their citizens while reducing emissions. India's policymakers and companies can use many technologies, policy and finance levers to deliver the energy required to meet the nation's economic aspirations while mitigating the impacts of climate change.

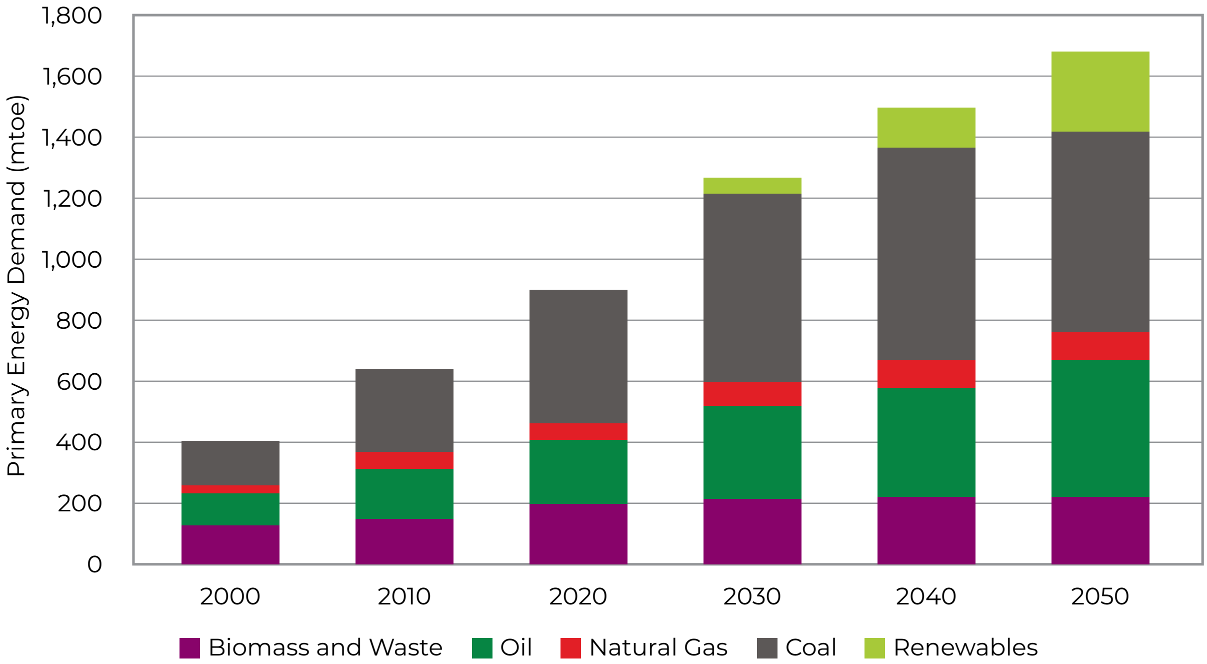
India's energy transition reflects its robust economic growth, with a fast-expanding middle class and rapid urbanization. The nation is the third-largest consumer of energy globally, according to data from S&P Global Commodity Insights. Total primary energy demand more than doubled from 2000 to 2020, surging to 937 million tons of oil equivalent (Mtoe) from 417 Mtoe. Still, India's energy consumption per capita is less than 1/10th of the US's. How India meets its growing energy demand and changes its primary energy mix over the coming decade will substantially influence global energy markets and help determine if, and when, global emissions targets are reached.

Securing Reliable, Affordable and Sustainable Energy Supplies

India's economy will average 6.7% per annum GDP growth from fiscal 2024 to fiscal 2031 and its increasing energy demand will have a sustained global impact. The nation's oil consumption will jump to 305 Mtoe in 2030 from 210 Mtoe in 2020, according to S&P Global Commodity Insights. Gas consumption will rise to 70 Mtoe from 53 Mtoe. Limited domestic supplies mean that India's oil imports will exceed 90% of demand by 2030 at 280 Mtoe. Gas imports will surpass 60% of supplies, at 44 Mtoe. Coal will buck the trend, with imports remaining at about 25%, due to India's own substantial resources. India already spends more than $160 billion of foreign exchange every year on energy imports, according to government statistics. The import bill is likely to double in the next 15 years without steps to reduce this import dependence. Higher imports will put a further burden on government finances.

Figure 1

India's Energy Demand to Double by 2050



Date complied January 1, 2023
Source : S&P Global Commodity Insights.
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Ensuring secure and affordable supplies of oil and gas is the highest energy priority for the government. There are several opportunities to reduce import dependence.

Upstream oil and gas:

Domestic exploration has yielded mixed results over the last decade with no new major discoveries. Renewed interest in India from international oil and gas companies is likely to have limited impact because these companies are reducing oil/gas investments while transitioning to a broader fuel mix. Still, there is potential to boost output at Indian oil/gas fields using secondary and tertiary recovery technologies. Average recovery factors in India are 20%- 30% compared with global averages of 35%-40%. The application of new technologies, including digital technologies, machine learning and data analytics, provides a further impetus to focus on improving recovery factors. High oil prices are another incentive for increasing domestic oil and gas production.

International assets:

Many oil and gas companies around the world are divesting oil/gas assets and focusing on energy transition to meet net-zero targets. Indian public sector oil/gas companies can pool resources and jointly bid for these assets. They can also partner with strategic international investors that want to access India's growing domestic energy market. Greater ownership of foreign oil/gas supplies will ensure energy security for India and help in managing price volatility.

Deployment of renewables:

Solar photovoltaic installations have grown 12-fold in India since 2015, based on S&P Global Commodity Insights data, while wind power capacity has doubled. Further accelerating deployment of renewables will be critical in achieving the government's target of increasing installed renewables capacity to 500 GW by 2030. This will help meet growing electricity demand while keeping prices affordable and cutting emissions. It will also reduce the impact of gas price volatility on power generation and support the retirement of old and inefficient coal power plants.

Hydrogen:

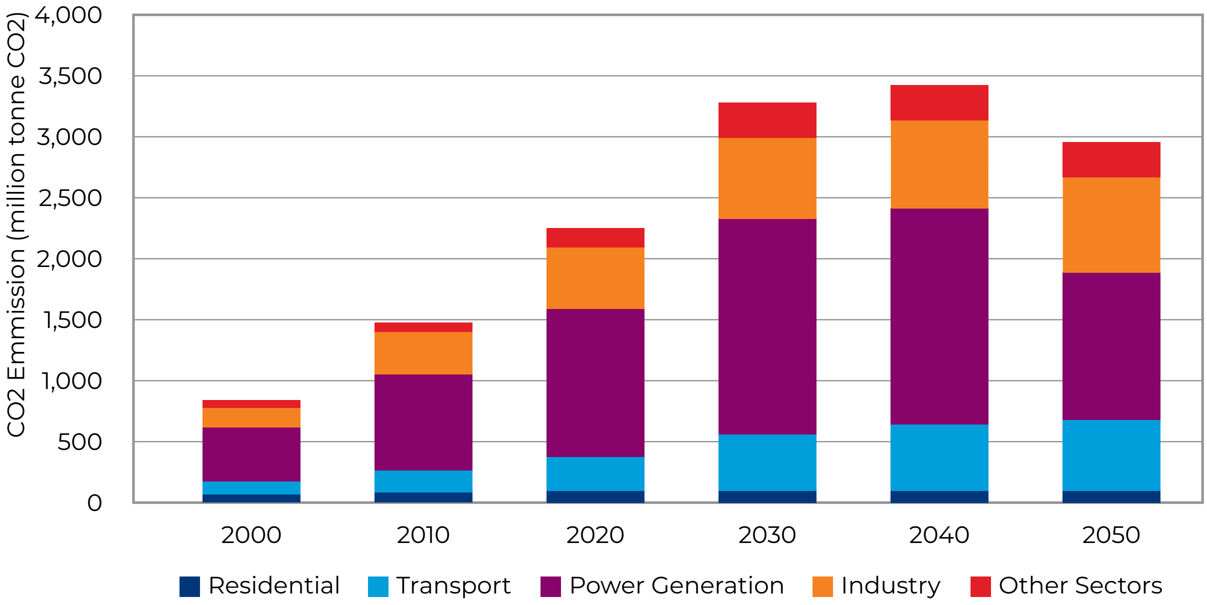
The government launched the National Green Hydrogen Mission earlier this year with the goal of producing 5 million metric tons of the fuel annually by 2030. This will help reduce fossil-fuel imports and turn India into a leading producer and exporter of green hydrogen. The government plans to sell 70% of output overseas. Domestically, hydrogen can be utilized for long- duration storage of renewable energy, as well as replacing fossil fuels in industry and heavy-duty transportation. It can also help to decarbonize India's steel sector and make a significant impact in reducing emissions.

Reducing Emissions

Any road to net-zero globally will have to travel through India. India's economic

Figure 2

Energy Sector CO2 Emissions to Peak around 2040



Date complied January 1, 2023
Source : S&P Global Commodity Insights.

growth coupled with rising demand for energy will result in a continuing increase in greenhouse gas emissions for the foreseeable future. The historical disparity of cumulative GHG emissions between the Global North and Global South is well acknowledged; however, effects of climate change are being felt around the world. India is seeing unprecedented temperatures, floods and droughts, as well as deteriorating air quality. Net-zero emissions targets are also likely to be superseded over the next decade by a focus on energy security and affordability.

Over the last decade, the focus has been on improving energy access via rural electrification and on ensuring affordability through targeted subsidies. Looking forward, India will have to strike a balance to increase energy access and reliability while delivering affordable energy supplies and diversifying its fuel mix to reduce the overall carbon intensity of its energy system. There are several pathways to reducing emissions.

Power sector:

Power generation is India's largest source of GHG emissions because coal provides over 70% of the country's electricity. It is unrealistic to rapidly reduce coal's share in the fuel mix, even with richer countries providing support through initiatives such as the Just Energy Transition Partnership. Nevertheless, aging and inefficient coal plants can be phased out, while newer plants can be cleaned up to meet more stringent emissions standards. The deployment of renewables can also be stepped up significantly by establishing a domestic clean-energy supply chain.

Transport sector:

Decarbonizing the transport sector will likely be more challenging than decarbonizing power. The sector can start by electrifying two- and three-wheelers, which account for about two-thirds of India's petrol demand. Deploying the infrastructure for these vehicles will be easier than setting up nationwide charging systems for light-duty vehicles. Mass transportation can also be fully electrified. Rapidly scaling up production of biofuels from agricultural waste would increase liquid fuel supply and reduce local air pollution.

Energy efficiency:

A nationwide initiative to accelerate energy efficiency could pay significant dividends. Other expanding economies have shown that it is possible to slow growth in energy demand with efficiency measures, which then eases emissions. Energy savings would come from industry, buildings and transportation.

Looking Forward

India and the rest of the world are joined at the hip in the journey to reach net-zero emissions. It will be a hollow victory if the Global North reaches net-zero, and the Global South remains far behind. Developing countries will be watching closely as India continues its growth trajectory while trying to reduce the carbon intensity of its economy and ultimately bend its total GHG emissions curve. The way ahead will not be straightforward; however, there are actions such as increasing investments in energy infrastructure, improving energy policy alignment and coordination and strengthening national champions that will enable the provision of secure, affordable, and sustainable heat, light and mobility to the citizens of India.

03

Low Carbon Energy Pathways for Sustainability

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Oil courses through the intricate veins of the global economy like life-giving blood, while Gas breathes vitality into the very lungs of its economic expansion. However, the whole story isn't as rosy as it may first appear. Currently, this narrative is haunted by a double whammy: on one side, there looms a threat of depleting fossil reserves, projected to last for no more than 52 years. On the other side, massive CO2 emissions spewed by industries reliant on fossil fuels have triggered urgent climate concerns. If these emissions are not halted, the global average temperature is projected to rise by over 2 degrees Celsius, rendering the world uninhabitable. This underscores the immediate need to discover sustainable solutions to address these perplexing twin issues. Sustainable fuels stand forth as the remedy for the present predicament and can be used as an alternative in transport sector which accounts for 14% of India's greenhouse emissions.

This article envisages to discuss about sustainable fuels and their various types, associated benefits and challenges and way forward.

Types of Sustainable fuels

1. Bio Fuels
2. Green Hydrogen
3. E-fuels

Bio- Fuels

Biomass refers to organic matter derived from living organisms, including plants and animals. It encompasses materials that store chemical energy acquired from the sun through photosynthesis, making it a renewable and sustainable energy source.

In this context, biomass represents a vital component of the natural carbon cycle, as it captures and stores solar energy in its chemical bonds during the growth process. When utilized for energy production, biomass can be converted into various forms such as biofuels, biogas, and even used directly for heat and power generation.

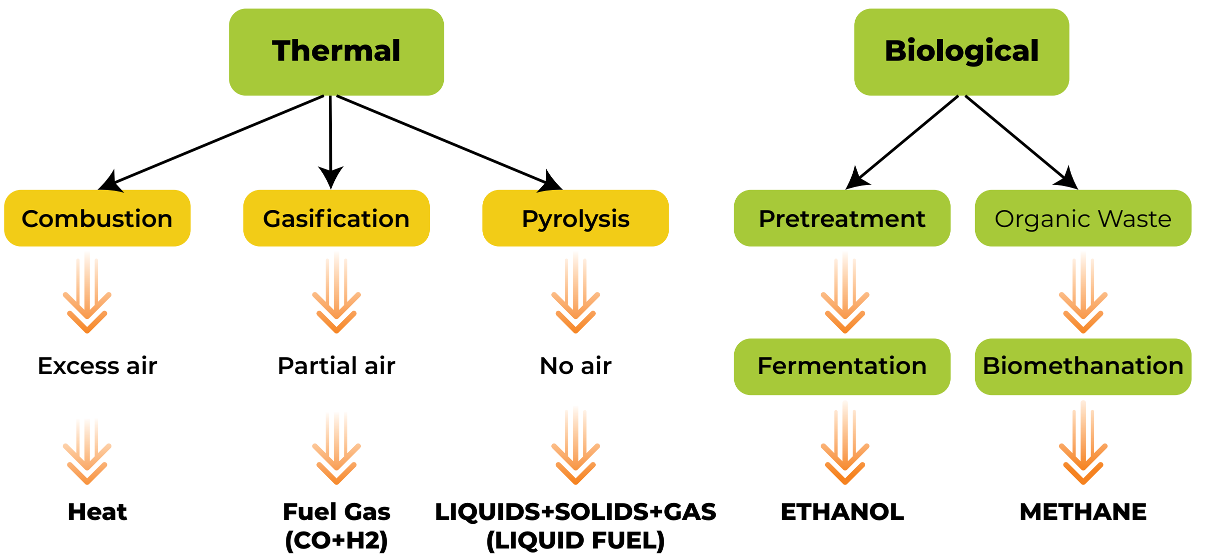
As per a recent study sponsored by MNRE, the current availability of biomass in India is estimated at about 750 million metric tonnes per year. The Study indicated estimated surplus biomass availability at about 230 million metric tonnes per annum covering agricultural residues corresponding to a potential of about 28 GW.

There are two main pathways of biomass conversion: thermal and biological.

Biomass can be burned by thermal conversion and used for energy. Thermal conversion involves heating the biomass feedstock in order to burn, dehydrate, or stabilize it. The most familiar biomass feedstocks for thermal conversion are raw materials such as municipal solid waste (MSW) and scraps from paper or lumber mills.

Figure 1

Bio Fuels Production Pathways



Biomass can also be directly converted to energy through gasification. During the gasification process, a biomass feedstock (usually MSW) is heated to more than 700° C with a controlled amount of oxygen. The molecules break down and produce syngas and slag.

Pyrolysis is a related method of heating biomass. During pyrolysis, biomass is heated to 200° to 300° C without the presence of oxygen. This keeps it from combusting and causes the biomass to be chemically altered.

Pyrolysis produces dark liquid called pyrolysis oil, a synthetic gas called syngas, and a solid residue called biochar. All of these components can be used for energy.

In biological methods bioethanol, biodiesel and Compressed Bio-gas (CBG) are the main biofuels produced. Depending upon the feedstock biofuels are further classified as 1st ,2nd ,3rd and fourth generation.

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.

Bioethanol

Bioethanol is utilized as a "drop-in fuel," capable of being seamlessly blended with existing gasoline, thereby reducing the consumption of fossil fuels and mitigating CO2 emissions. Worldwide countries have relied on their various ethanol blending programmes. Ethanol blending (EBP) with gasoline like 5% (E5), 10% (E10), 20% (E20) etc. are being used in practice. Ethanol blended gasoline has reduced emissions as compared to neat gasoline – One Crore litre of ethanol blended petrol can save around 20,000 tons of carbon dioxide (CO2) emission. Greenhouse gas emissions due to the EBP Programme lowered by 192 lac tons from 2014 to 2021.

Table 1

Emissions of E10 & E20 Blends in Gasoline [1]

Emissions	Gasoline	Two-wheelers		Four-wheelers	
		E10*	E20*	E10*	E20*
Carbon Monoxide	Baseline	20% lower	50% lower	20% lower	30% lower
Hydrocarbons	Baseline	20% lower	20% lower	20% lower	20% lower
Oxides of nitrogen	Baseline	No significant trend	10% higher	No significant trend	same

In 2002 the Government of India decided to launch the sale of 5% EBP in nine States and four Union Territories (UTs) with effect from January 2003. Based on these promising experiences, the MoP&NG in 2006 extended the 5% Ethanol Blended Petrol to twenty States and four UTs of the country.

National Policy on Biofuel 2018 laid down indicative target of 20% blending of ethanol in petrol and 5% blending of biodiesel in diesel by 2030 in the country. India achieved the targeted 10% ethanol blending in May 2022, 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%.

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 as below.

Table 2

Ethanol Demand Projection[1]

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

For FY 2025-26, ethanol requirements would be about 1,016 Cr Litres to achieve 20% blending and the total requirement of alcohol, including other sectors, would be 1,350 Cr Litres.

Under PM-JIVAN scheme, 12 commercial plants and 10 demonstration plants of Second Generation (2G) Bio-Refineries (using ligno-cellulosic biomass as feedstock) are planned to be set up in areas having sufficient availability of biomass so that ethanol is available for blending throughout the country.

To meet the blending requirement, supply side capacity augmentation is required as –

Table 3

Ethanol Capacity Augmentation (20% blending by ESY 2025-26) [1]

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

Biodiesel

In the National Biofuels Policy 2018, India set a target of 5% biodiesel blending in diesel by 2030. 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. litres of biodiesel would be needed in 2023. The consumption of HSD is expected to be 16,900 Cr. litters by 2030, thus, demand for biodiesel will grow to approximately 845 Cr. litters by 2030.

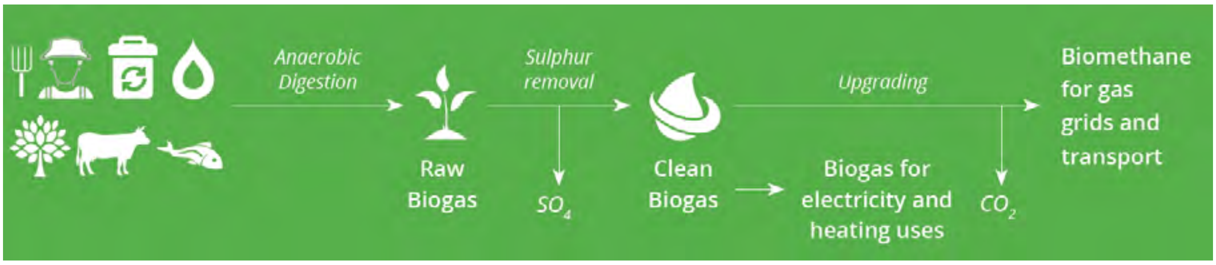
India maintains 10 biodiesel plants with a combined 60 Cr litres capacity. Primary biodiesel feedstocks include non-edible industrial oils, UCO, animal fats, and tallows. However, limited availability of raw materials has resulted in infrequent production. In addition, the high price of crude edible oils, including palm oil and palm stearin have decreased the operational efficiency and profit margins.

Compressed Bio Gas (CBG)

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.

Figure 2

Compressed Biogas (CBG) Production Process [2]



Waste and bio-mass sources, including agricultural residue, cattle dung, sugarcane press mud, distillery spent wash, municipal solid waste, and sewage treatment plant waste, undergo anaerobic decomposition to produce biogas. This biogas is then purified to eliminate hydrogen sulphide (H_2S), carbon dioxide (CO_2), and water vapor, and compressed to create Compressed Biogas (CBG) or Bio-methane, which contains over 90% methane (CH_4) content.

Biogas is considered a greener fuel since it contains a higher hydrogen-to-carbon ratio than other fuels, and its combustion leads to reduced carbon dioxide emissions. Biogas requires a purification process (known as biogas upgrading) to allow its direct use in combustion engines, gas turbines, or fuel cells. Compressed Biogas (CBG) came on the Government agenda only in 2018 when the Ministry of Petroleum and Natural Gas (MoPNG) launched Sustainable Alternative towards affordable transportation (SATAT).

SATAT' (Sustainable Alternative Towards Affordable Transportation) initiative on CBG envisages production of 15 MMT CBG & 50 MMT of manure from 5,000 plants.

Various technologies are available for CBG production, such as Anaerobic Digestion using methods like continuous stirred tank reactor (CSTR), plug flow, 2-stage reactors, and Upflow Anaerobic Sludge Blanket (UASB). Following biogas production, hydrogen sulphide is purified using ferric chloride, iron chelate, biological processes, or activated carbon.

Sustainable Aviation Fuel (SAF)

Aviation is considered one of the hard-to-abate sectors, accounting for about 3% of global greenhouse gas emissions. This percentage is likely to increase further with economic growth and the wider adoption of air travel. In our pursuit of achieving net-zero emissions, it becomes essential to decarbonize the aviation industry and embrace sustainable fuels.

Sustainable Aviation Fuel (SAF) is a drop-in fuel that can be easily blended with existing aviation fuel. It is derived from various renewable resources, including biomass, algae, waste, and green hydrogen. SAF can significantly reduce life cycle greenhouse gas emissions compared to conventional jet fuel. While one kilogram of conventional jet fuel emits 3.16 kilograms of CO_2, SAF, on the other hand, offers an impressive reduction of up to 80% in lifecycle carbon emissions. This reduction depends on the sustainable feedstock used, the production method, and the supply chain to the airport.

During COP-26, the International Civil Aviation Organization (ICAO) adopted a market-based measure known as the Carbon Offsetting Reduction Scheme for International Aviation (CORSIA). This scheme mandates aircraft operators to purchase “emissions units” to offset any CO_2 emissions increase beyond a 2019 baseline. In its Phase-I from 2024 to 2026, CORSIA applies to voluntary countries, while in Phase-II from 2027 to 2035, it becomes mandatory for all countries regarding their international flights. Aligned with CORSIA’s 2027 deadline, India’s Civil Aviation

Ministry aims to produce 100,000 tonnes of SAF by 2030. Given India's substantial biomass production, the country is well-positioned to generate SAF, and its National Biofuels Policy can play a significant role in boosting SAF production.

Moreover, a number of companies in India are developing bio-based SAF production technologies. Indian Oil Corporation is developing a bio-based SAF production plant at Panipat, Haryana. MRPL plans to produce 10,000 tonnes of SAF per year using the HEFA (Hydro-processed esters and fatty acids) process.

Challenges

Although biofuel offers numerous benefits, its widespread adoption currently faces some challenges that need to be addressed.

- India's EBP programme faces some supply constraints. To achieve E20 blending India needs 1350 Cr ltr supply of ethanol which is almost twice of the existing capacity of 684 Cr ltr. India's growing production and consumption of ethyl alcohol in the potable sector, as well as in chemical and industrial applications will continue to compete for sugarcane and grain feedstocks that remain insufficient to supply all sectors.
- Ethanol-blended gasoline raises the research octane number (RON); however, its 2/3 calorific value compared to gasoline curbs engine efficiency. Yet, the elevated octane number allows for high compression ratio operation, preventing knocking and ultimately enhancing engine efficiency. This, coupled with precise spark timing, offsets the fuel economy impact of ethanol's lower calorific value. Therefore, technological modifications are required to improve efficiency and it becomes necessary when going beyond 20% blend.
- In spite of various policy initiatives in place CBG, related development is yet to take off. Currently, it faces many challenges in terms of long-term consistent feedstock supply and scale of economies.
- SAF faces some challenges in term of consistent feedstock, processing technologies and its resultant high cost. Currently, SAF is about 2 to 5 times costly compared to conventional jet fuels depending upon the feedstock.

Green Hydrogen

Green hydrogen is becoming an interesting and powerful strategy to developing countries to support their national sustainable energy objective while meeting environmental, and decarbonization strategies. Domestic production of hydrogen from renewable electricity will significantly reduce energy imports, whilst supporting a domestic energy industry. Green hydrogen thus offers an economic opportunity for policy makers to develop local industry.

Green Hydrogen is produced by electrolysis of water using renewable electric source. However, at present, it is not cos-effective to produce it at the large scale but it is expected to become economically viable by 2030. India has launched its ambitious National Green Hydrogen mission which aims to produce 5 MMT of

Green Hydrogen per annum with associated renewable energy capacity addition of 125 GW. With an expected price decline for both electrolysers and renewables, it is expected that in the best-case scenario, the cost of green hydrogen can fall to approximately $1.60/kg by 2030 and $0.70/kg by 2050.

Electrolysis of Water-

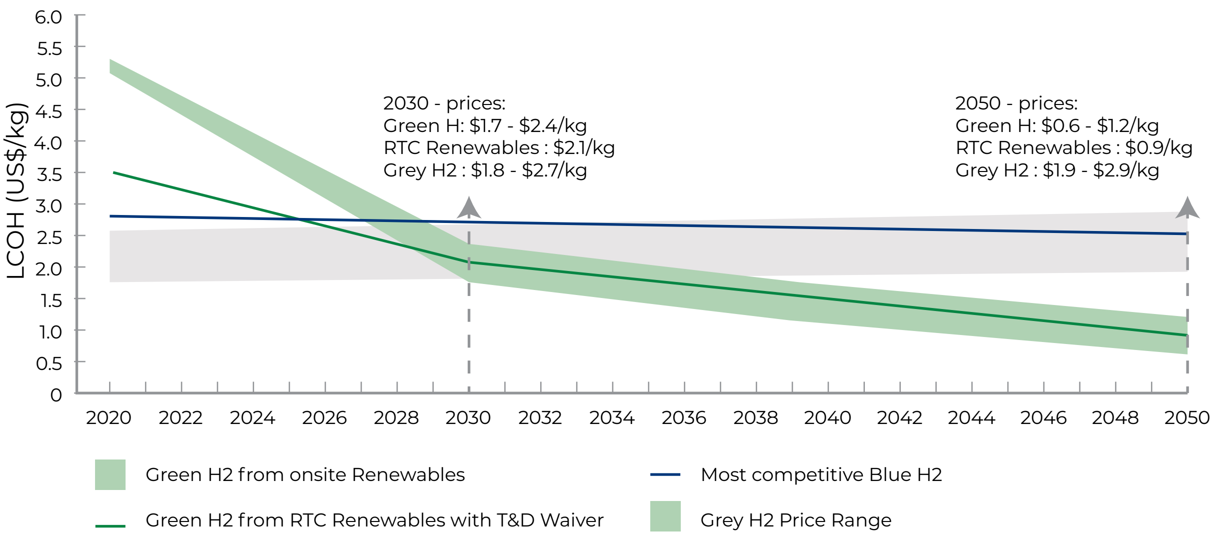
Electrolysis is a promising option for carbon-free hydrogen production from renewable energy source. Generally, two electrodes (cathode and anode) are used in an aqueous solution containing KOH electrolyte as shown in Fig. This unit is known as electrolyser. Electrolysers can be small and large based on small scale and large-scale hydrogen production respectively. Hydrogen production via electrolysis can be made completely zero greenhouse gas emissions depending upon the source used to provide energy to split water molecule.

There are four types of electrolysers namely, Alkaline water Electrolysers (AEL), Proton Exchange membrane electrolysers (PEM), Anion exchange membrane Electrolysers (AEM) and Solid Oxide Electrolysers (SOE).

With larger scale production and advancement of technology, electrolyser's efficiency is expected to improve. More efficient electrolysers and reduced cost of renewables in tandem reduce the cost of green hydrogen and make it cost-competitive with grey -hydrogen.

Figure 3

Projected Price trajectory of Solar Green H2 Production [3]



Hydrogen from Biomass

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. Biomass / MSW gasification can also play a critical role for production of green hydrogen in India.

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. 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.

The tentative cost of hydrogen from different pathways are summarized in the table-4 below-

Table 4

The tentative cost of hydrogen from different pathways

Process	Feed Type	Feed Cost (₹/ kg)	Efficiency (%) – Feed to H2	Tentative H2 cost -mass production (₹/kg)
Gasification	Coal/ Biomass	4-5	65-68%	~150-170
Bio methanation to H2	Agro Residue	3-4	50%	~250-270
Natural gas Reformer (If CCUS is added, then ₹ 35-40/kg) will be additional	NG	40	75-80%	~140-160
Solar Electrolysis Power	DI Water (9 litre /kg)	27 + Electricity Cost	~11% (solar to hydrogen)	~300-325
Aqueous Phase Methanol Reforming	Coal/NG to ethanol to hydrogen	23-25	~32-40%	~200-220
Photoelectrochemical Water Splitting Process (Under Development)	DI water	Advantages over other processes: Completely green hydrogen. Suitable for both centralized and distributed application		

Challenges: -

Hydrogen, while not an energy source itself, is a promising energy carrier with many potential benefits for the energy transition. However, as it is still in its early stages of development, there are a number of challenges that need to be addressed-

- The major challenge with hydrogen lies in making it price-competitive with grey hydrogen. Currently, green hydrogen costs almost five times as much as grey hydrogen, which presents a significant obstacle to its widespread adoption. However, technological advancements are anticipated in the realm of electrolysers, further enhancing their efficiency. Additionally, the cost of renewable energy is expected to decrease in the foreseeable future, ultimately enabling green hydrogen to become price-competitive with grey hydrogen.

- The second challenge associated with green hydrogen pertains to its storage and transportation. Storing green hydrogen, which essentially requires high pressure or cryogenic conditions, presents certain safety and economic challenges., Although, its transportation is relatively economical through pipeline but there are serious concerns regarding hydrogen's propensity for causing embrittlement in materials. Hydrogen due to its smaller molecule size can permeate into metal pores and thus make it susceptible to crack. The behaviour of hydrogen within pipelines is a subject that requires thorough study before large-scale adoption. In collaboration with PSU's, CHT has proposed the "Hydrogen Test Loop" project, aimed at studying the behaviour of hydrogen blends in existing piping.
- Green Hydrogen development, which is at initial stage in our country, is often plagued by lack of clear regulatory framework, policies and safety standards in place.

e-Fuels

E-fuels encompass a wide range of synthetic fuels, including e-hydrogen, e-methane, e-methanol, and e-gasoline produced through various electrochemical processes. e-fuels are synthetic fuels, produced by electrolysis of water with renewable electricity and CO_2 captured either from a concentrated source (e.g., flue gases from an industrial site) or from the air (via direct air capture, DAC). E-fuel is nearly carbon neutral in theory. They can be manufactured as 'drop in' replacements for fossil jet fuel, diesel and fuel oil. E-fuels are also referred to as electro-fuels, power-to-X (PtX), power-to-liquids (PtL), power-to-gas (PtG) and synthetic fuels. The most common conversion pathways for liquid fuel synthesis are the Fischer-Tropsch (FT) pathway and the methanol (MeOH) pathway. These technologies are well-known and used at scale. However, current processes use fossil carbon sources, and new technologies and further innovation will be needed to enable the use of non-fossil carbon dioxide sources.

In the energy transition to the Hydrogen economy, the e-Fuels will play an important role in decarbonization, while saving on major infrastructure changes. Ammonia and Methanol are easy to transport, store and use as compared to Hydrogen in industries like marine, Fertilizer, Electricity production and utility in mobility sector.

E-Fuels Technology

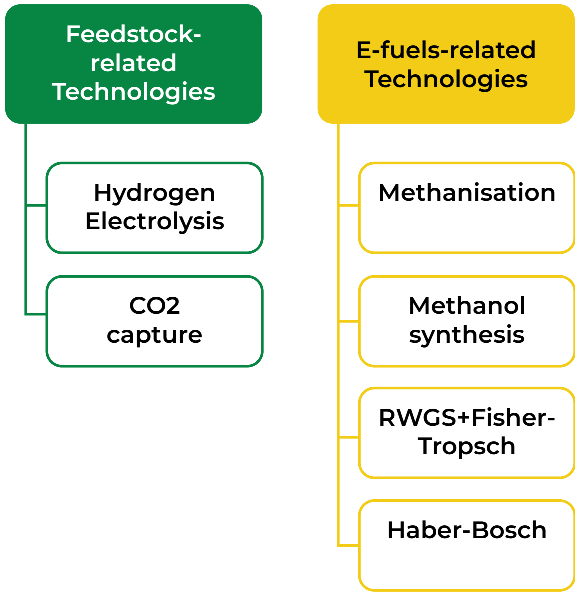
Hydrogen Electrolysis

Different electrolysis technologies can be used for producing hydrogen.

CO2 capture

he production of e-fuels requires CO_2 (except e-ammonia), which can be obtained from various sources including biomass combustion, industrial processes (e.g., flue gases from fossil oil combustion), biogenic CO_2, and CO_2 captured directly from the air (DAC).

E-fuels production routes consist of e-hydrogen reacting with captured CO_2, followed by different conversion routes according to the final e-fuel (such as the methanisation route for e-methane; methanol synthesis for e-methanol, e-DME, e-OME or e-liquid hydrocarbons; or the reverse water-gas shift **(RWGS)** reaction to produce syngas + Fischer-Tropsch synthesis to produce e-liquid hydrocarbons, such as e-gasoline, e-diesel or e-jet. To produce 1 litre of liquid e-fuel is 3.7–4.5 litres of water, 82–99 MJ of renewable electricity and 2.9–3.6 kg of CO_2 is needed.



E-ammonia does not require CO_2 and is synthesised from e-hydrogen through a **Haber-Bosch reaction**.

E-Fuel Challenges

India is moving towards becoming the world's 3rd largest automobile market in the next few years. There is growing concern about the use of fossil fuels due to the rising cost of oil imports, increasing air pollution, carbon dioxide emissions, and depleting reserves of mineral oils such as gasoline and diesel. E-fuels have the potential to decarbonize the transportation sector by providing a drop-in replacement for fossil fuels. However, there are a number of challenges that need to be addressed before e-fuels can be widely adopted. Few of them are-

E-Fuel Cost

The Production costs for e-fuels are currently more expensive than fossil fuels. The e-fuels production process is inherently inefficient, converting at best half of the energy in the electricity into liquid or gaseous fuels. The energy losses from manufacturing are high due to the many processes involved. However, this might be justified where electrical propulsion is not practical and renewable electricity is cheap and plentiful. Innovation in each process stage has the potential to reduce these costs in the future to enable production and scale up.

e-fuel costs are currently relatively high (up to 7 $/ liter) but are expected to decrease over time due to economies of scale, learning effects and an anticipated reduction in the renewable electricity price; this is expected to lead to a cost of 1–3 $/ liter (without taxes) in 2050. The cost of e-fuels could therefore be 1–3 times higher than the cost of fossil fuels at that time.

Efficiency

The overall energy efficiency of e-Fuels is very less as compared with BEVs and FCVs. e-fuel production is still relatively low because 48% of the energy from renewable electricity to be lost in conversion to liquid fuels, using the average value for drop-in diesel technologies. Then 70% of the energy in those fuels will be lost when they are combusted in internal combustion engines, for a total efficiency of 16% for the e-fuels pathway. This means that a lot of energy is lost in the process, which drives up the cost. The efficiency of e-fuel production is expected to improve over time, but it is still a major challenge that needs to be addressed.

Regulatory challenges

The regulations governing the production and use of e-fuels are still being developed. This could slow down the commercialization process. The regulations for e-fuels need to be clear and consistent in order to encourage investment and innovation.

E-Fuel Advantages

- E-fuels can achieve significant reductions in carbon emissions compared to fossil fuels. The potential for CO2 abatement is estimated to be between 85 and 96% on a well-to-tank basis, or 70% on a life-cycle basis.
- Liquid e-fuels are easier (and relatively inexpensive) to store and transport compared to electricity.
- E-fuels have a higher energy density than electricity, making them a viable alternative for aviation and shipping applications where electricity-based alternatives are not available.
- Existing infrastructure for transportation and storage can be used for e-fuels.
- Some e-fuels could be deployed immediately across the whole transport fleet without any major changes in engine design.
- E-fuels produce fewer pollutants than fossil fuels, such as nitrogen oxides and sulphur oxides. These pollutants can contribute to smog, acid rain, and respiratory problems.

Conclusion

Biofuels, green hydrogen, and e-fuels are all low-carbon energy pathways that have the potential to play a critical role in the sustainable development of our country. Biofuels can be used to replace fossil fuels in a variety of applications, including transportation, heating, and power generation and they have the potential to reduce greenhouse gas emissions, but they can also have a negative impact on land use and water resources. Bio-based SAF production and CORSIA implementation are two key strategies for reducing greenhouse gas emissions from aviation. Green hydrogen is a clean and efficient fuel that can be used to power vehicles, heat homes, and generate electricity. Green hydrogen is still in the early stages of development, but it has the potential to be a major player in the low-carbon energy market. E-fuels are synthetic fuels that can be used in place of fossil fuels in transportation and other applications. E-fuels represent a promising pathway towards a sustainable energy future, offering a means to store renewable energy and decarbonize challenging sectors, but they are also expensive to produce.

In conclusion, this paper has provided a brief overview of three low-carbon energy pathways: biofuels, green hydrogen, and e-fuels. These pathways all have the potential to play a critical role in the sustainable development of our country, but the choice of which low-carbon energy pathway to pursue will depend on a number of factors, including the cost, availability, and environmental impact. More research is needed to develop and deploy these technologies at scale, but they have the potential to revolutionize the way we produce and consume energy.

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Clean Energy and India's G-20 Presidency: Global Alliance and Climate Finance

04

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February 2023 was an important month for India's commitment to the global energy transition as the country hosted the first G20 'Energy Transition Working Group' (ETWG) meeting (5-7 February) under its G20 Presidency, launched the 'India Energy Week' (6-8 February), especially the 'E20 fuel' (20% Ethanol and 80% Petrol) at the India Energy Week and the 'Global Biofuel Alliance'. The common priority issue in all these events was 'Biofuels'. Biofuel, as defined by the United Nations Framework on Climate Change (UNFCC) is "a fuel produced from dry organic matter or combustible oils produced by plants. These fuels are considered renewable as long as the vegetation producing them is maintained or replanted, such as firewood, alcohol fermented from sugar..." This alternative to fossil fuels is increasingly gaining importance due to its roles in reducing greenhouse

gas emissions (GHG) and increasing energy security. It is an example of modern bioenergy and is commonly produced in the form of bioethanol, and biodiesel. Adopting biofuels in sectors such as steel, chemicals, and automobiles would strengthen global efforts toward achieving SDG 7 of ensuring access to affordable, reliable, sustainable, and modern energy for all.

There are significant producers of biofuels amongst the G-20 members such as the U.S. which is the largest producer (1435 petajoules) of biofuels, followed by Brazil, Indonesia, and China among others. India also produces biofuels and implemented policy initiatives in this direction through the 'National Policy on Biofuels (2018)', last amended in 2022. The production of biofuels as an alternate fuel was given an unprecedented importance as early as the 1970s in the then foreign-oil-dependent countries such as the U.S., and Brazil. It was mainly driven by the OPEC oil embargo threatening energy security and national economies, resulting in a shift of focus to the domestic production of bioethanol, a biofuel substitute for petrol. Together, these two countries produce 70% of the global biofuels, and, in fact, Brazil's bioethanol model is considered the ideal sustainable biofuel system in terms of the industry as well as the economy. It is a takeaway for developing countries, especially agrarian-based emerging markets. India has notably already built strategic bilateral partnerships with Brazil and the U.S. in the form of an MoU (2019) and a Joint Working Group (2009) respectively. These partnerships aim to secure knowledge sharing, transfer of technology, and investment promotion in the bioenergy sector.

India, though a late starter in utilizing bio-ethanol as a fuel, has admirably leaped by increasing the blending of ethanol in petrol from 1.53% in 2013 to 12% in 2023, the same level that the USA is blending though they started in 1990. Under the updated Ethanol Blended Petrol Programme (EBP), India aims to achieve 20% blending by 2025-2026 against the initial target year of 2030. Reportedly, 1,000+ crore litres of ethanol would be required for meeting the 2025 target against the current production of 700 crore litres. Being the second largest producer of sugarcane in the world, India produces ethanol by processing sugarcane and molasses as primary raw materials followed by rice and maize, i.e., First Generation (1G) bioethanol. 1G is the most produced biofuel in the world, the U.S. uses corn, and Brazil, sugarcane as the primary feedstock for producing ethanol.

However, there are potential bottlenecks concerning the use of 1G biofuel. The use of food items as feedstock for the production of bioethanol has attracted criticism from different environmental groups. The major concern arising out of the diversion of food for the production of 1G bioethanol is food security. Further, the fertilizer requirement for the production of the 1G bioethanol feedstock will aggravate the condition of net fertilizer import for nations such as India. Furthermore, there are implementation challenges of technology for increasing the blending percentage of ethanol as the auto manufacturers and other fuel-dependent industries would have to develop compatible engine technology for higher ethanol blending percentages.

To move towards more sustainable production and to avoid competition between ethanol for fuel blending and food resources, advanced biofuels such as 2G bio-ethanol made from agricultural waste, 3G(microorganisms), and 4G (electro fuels/ solar fuels) have to be scaled up instead of the current 1G bio-ethanol. Transitioning to advanced technologies would eliminate issues such as the dependence on water for irrigation to produce the feedstock and reduce the resulting carbon emissions even further. Currently, 2G biofuel production incurs high capital costs which can only be resolved through technological advancement. Similarly, 3G and 4G biofuels are in the nascent stage of research and development and require greater intellectual and financial investments for a fast-paced development and subsequent deployment. There are a few ongoing projects in India that use Public-Private Partnerships, with financial assistance from the Govt of India, to establish bio-refineries for producing the 2G ethanol required for blending in petrol. These Model 2G bio-refineries would aid in deploying foreign licensed technologies in India to a limited extent.

If countries could work together, rather than in silos, to collaborate in research & development, deploy biofuels technologies, and alter vehicles to run on biofuels, every member and the world at large will be gaining from reduced emissions and improved energy security due to the resulting accelerated adoption of biofuels. Through widespread adoption of biofuels, counties can ensure higher farmer income as the feedstock for biofuels will increase the realized prices for farm products and create a new market for the farm waste that is discarded now. An alliance could also ensure coordinated and concerted efforts by multiple countries to standardise regulations, adopt policy initiatives, and explore possible trading opportunities. It will also aid in securing improved financing options for biofuel projects, especially for developing and least developed countries (LDCs).

Against this backdrop, collective efforts towards innovative financing solutions such as assistance from multilateral development banks (MDBs) could help the world step closer to achieving its climate targets. An alliance could potentially channel funds and initiatives such as those announced by the MDBs vis-a-vis climate finance targets worth US$50 billion for developing countries and LDCs for 2020-2025 since they first began climate financing in 2011. MDBs have a strategic role to play in developing the renewable energy sector of developing countries and LDCs against risk-based barriers to finance. These countries have lower credit ratings than developed nations due to high political, regulatory, and economic risks, among others, and low-returns, making the former nations a low priority for the relatively risk-averse private capital. MDBs can be roped in for providing investor assurances through risk-mitigation tools such as credit enhancement schemes and blended financing.

MDBs could channel the flow of private finance into sustainable energy projects by providing loan guarantees which would increase the creditworthiness of green projects in capital-risky destinations, attracting increased investments. For e.g., the Asian Development Bank (ADB) offers credit guarantee schemes i.e., partial credit guarantees and political risk guarantees. The ADB runs a partial guarantee scheme in India; it provides partial guarantees on rupee-denominated bonds issued by Indian companies to finance infrastructure projects. The impact of credit enhancement schemes by MDBs is multiplied as it helps in mobilizing private sector finance, with the highest share of financing at 46% in developing countries in 2017-18 as reported by OECD. Another risk-mitigation tool is blended financing, which includes concessional funding and commercial funding. The blending of public and private finance will mitigate the risk for private capital. In the long run, once the risk perception is eliminated, private capital will be the standalone financing option for future green energy projects in developing counties and LDCs. According to reports, blended finance has mobilized US$ 171 billion in developing countries from 2011-2022

These financing options are currently not leveraged to the desirable level by LDC and developing nations, including India. The experience from leading the International Solar Alliance will help India catalyse the global shift toward biofuels through an alliance on biofuels. By conceiving such an alliance at the G20 Presidency, India can potentially augment the future energy security challenges of many nations including its own, improve the global farming community at large, and lead as a developing country in achieving global climate targets.

Energy Transition - Expectations and Realities

05

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Introduction

What is Energy? Surprisingly, even Noble Prize winners have great difficulty in giving a satisfactory answer to this simple question. In his famous Lectures on Physics, Richard Feyman (l 918-1988) stressed, "it is important to realize that in physics today, we have no knowledge of what energy is. We do not have a picture that energy comes in little blobs of a definite amount"(Feynman, 1988). The generic meaning of transitions-as passage from one condition of action to another-a quite straight forward and hence readily understood, but adding Energy qualifier complicates the comprehension. There is no formal accepted definition of Energy Transition but is most often used to describe the change in composition of primary energy supply, the gradual shift from a specific pattern of energy provision to a new state of energy system. This change can be traced on scale local to global, and universally experienced transition from biomass to fossil fuels is certainly the best example. The only thing large scale energy transitions have in common: because of requisite technical and infrastructure imperatives and because of numerous (often entirely unforeseen) social and economic implications, energy transition taking place in large economies or at global scale are inherently protracted affair. It also has history of repeated failed predictions of imminent triumphs of new sources or new prime movers. Barring some extraordinary and entirely unprecedented financial commitments and determined action-none of today's promise of greatly accelerated energy transition from fossil fuel to renewable energies will be realized (Smil, 2010). We look at some challenges.

Patterns from History

Lessons of past energy transitions may not be particularly useful for appra1smg and handicapping the coming transition because it will be increasingly difficult to restructure the modem high-energy industrial and postindustrial civilization on the basis of non-fossil fuel that is overwhelmingly renewable -fuels and flows (Smil, 2010). All earlier transitions also happened from lower energy density fuel to higher energy density fuels. Energy density of dry phytomass has a fairly uniform energy density of about I 8MJ/kg while air-dry wood, the most important fuel for household heating and cooking contains about 15MJ/kg. Next stop of transition was to coal which has energy density ranging from 8MJ in case of low-quality lignite's to 30MJ /kg for best anthracites. Next age of industrial revolution brought the society to Hydrocarbons where crude oils have much more uniform energy density of 40-42MJ/kg. Natural gas also varies between 35-40MJ/kg. In terms of energy densities coming shift to renewables is movement in the opposite direction vis a vis history. Transition to non-fossil fuels rests on less energy dense biofuels whose larger mass will require more handling and more storage. Even the ordinary coals have 30-50% more energy than air-dry wood and biomass burning power plant will have to be 30-50% larger. Similarly, Ethanol has an energy density of 24MJ/l, 30% less than gasoline. Biodiesel has energy density about 12% lower. This is a smaller problem compared to inherently lower power densities of converting renewable energy flows into mass produced commercial fuels or into electricity at GW scale. (Smil, Energy and Civilization-A history, 2018)

Scale and speed challenges

In 1890 when biomass slipped just below 50% of world's primary energy supply less than 20 EJ of fossil fuel supply was needed to substitute all the remaining biomass energy. By 2010 global use of fossil fuel energy ran up to 400EJ. This ran up to 500EJ in 2019. Thus, renewables required to replace fossil fuels went up by 25 times. Contrary to cornucopia of renewable flows there is only one kind of renewable energy that is so large that even if we capture of a mere 0.1% of its land flux it would satisfy global energy requirement almost twice as large as today. Solar powered electricity reached 3.6% of total electricity generated in the world in 2021 (TEA, 2021). This is quite an acceleration in last 10 years when it was mere 0.1% in 2010 (Smil, Energy-

Myths and Realities, 2010). Comparing time spans of successive fuel transitions reveal some remarkable similarities. Coal replacing biofuel reached 5% mark around 1840; it captured 10% of global market by 1855, 15% by 1865, 20% by 1870, 25% by 1875, 33% by 1885, 40% by 1895 and 50% by 1900. Milestone of liquid oil displacing coal and biofuel was 5% mark around 1915 and is virtually spaced at almost similar interval but oil never captured 50% of fuel market. However, natural gas, considered greener fuel by some has taken significantly longer period to reach 25%. It was at 1% way back in 1900. In world energy basket it stands at 24% as of 2020 but serious geo-political disturbances and wars are also not helping its cause even though it has 15kg of carbon/GJ vis a vis 30kg/GJ for coal and 20kg/GJ for oil. Global community is looking at NET ZERO by 2050. Bill Gates says in his book, "There are two number you need to know about climate change. The first is 51 billion. The other zero" (Gates, 2021). Fifty-one billion is how many tons of greenhouse gas world typically adds to atmosphere every year. Zero is what we aim for. Time period generally agreed upon is by 2050. Therefore, this not energy transition but 'Energy Replacement' of around 83% of primary source of energy, which are fossil fuels and it, is to be achieved in flat 28 years. Bill Gates says considering past energy transitions history is not on our side (Gates, 2021).

Options for Down Stream oil Industry in India

National Transition: Commonalities and Particularities

Indian energy demand is rising in all scenarios whether it is as per stated policy scenario or net zero scenario. In case of oil, also there is a rise in the demand up to year 2040. India has declared its Net Zero target for 2070 and currently it has very low per capita emissions. At the same time CO2 rise in the atmosphere is truly global phenomenon, which are being constantly monitored at Mouna Loa observatory in Hawaii since 1957. They have increased from 295ppm in 1900 to 419ppm in May 2021. This leaves less headroom for every nation irrespective the emissions they are contributing to the global kitty (NOAA, 2021). Now the challenge before oil industry, which is largely downstream in India, is that existing business of transport fuels, industrial fuels, marine fuels, aviation fuel and LPG is growing and will be on upswing in our country and then by 2040 it will start declining, more sharply after 2050. Capital investments in oil industry are very large and payback periods are long. Public sector oil companies have made a total capital commitment of Rs five lakh crores in next 5 years and in next year alone PSU oil companies will invest 1.11 lakh crores. India has total installed refining capacity of251MMT, and our consumption of refined products was 201MMT. India is large exporter of refined products with Europe being its main market. Total pipelines of crude, natural gas, and POL products is 55295 Km (Petroleum, 2022). Companies are investing hugely on pipeline infrastructure. Major expansion projects of a11 companies including addition of Petro Chemicals is in progress. A mega refinery in West Coast is also on anvil. Therefore, the dilemma is when to stop investing in existing business so that they are not saddled with stranded assets when electrification mainly thru renewables starts dominating. Situation in European oil industry is very different and so is their strategy. They are transitioning, at least as per their declared intent, from Oil & Gas companies to Gas& Oil companies and finally Energy companies with substantial capital commitment to renewables, biofuels, green hydrogen, and new sustainable technologies. Those changes are yet to become significant on their balance sheet. Ben van Beurden, chief executive officer of Royal Dutch Shell had stated that difficult part of strategy is where to invest during energy transition, but more difficult part of strategy is when to withdraw from existing businesses which generate cash. It will be long time before new businesses will give any returns, but they require investments upfront.

Down Stream Oil Industry in India - Transforming in sync with 'Climate of Change' in India with climate change

India's Major choice dimensions are:

- Role of Hydrogen in economy
- New mobility platforms: Electric vs. H2 based vs. Bio
- Role of bioenergy in economy (Direct combustion for industrial heat generation; for combined heat and power generation; Anaerobic digestion to generate biogas for both heat boilers and CHP plants; Fermentation & blend to produce bioethanol)
- Extent of nuclear (assuming Thorium technology)

Some key drivers in India's Energy Transition which may become bedrock of strategies of oil companies as they transform themselves in line with India's transformation agenda (Sudeep Maheshwari, 2022):

Power

- Solar +wind grow by 22X
- Coal peaks by 2040; Phase out by 2070
- Nuclear- IOX capacity
- Gas as a transitional fuel

Mobility

- Electric
- Hydrogen
- Ethanol
- Methanol (Shipping/Trucking)
- Ammonia (Shipping)

Industrial

- Halving of industrial energy intensity of total GDP
- Significant ramp up in Hydrogen offtake
- Coal peaks by 2040; Phase out by 2070

Refineries

- Peak crude oil consumption by 2050; drastic decline by 2070

The track oil industry in India is likely to follow along with timeline can be following:

Wave 1 (Time to act now)

1. Switch to renewables
2. Catalyzing Hydrogen economy
3. Efficiency measures in refineries/operations
4. Gas adoption acceleration

Focus on No Regret moves that are well aligned to long term India mega trends

Wave 2 (Time 3-5 years)

1. Accelerated bio-energy adoption
2. World scale Ammonia/Methanol capacity
3. Retail of future

Focus on large capex outlays based on Energy Transition scenarios and detailed market assessment.

Wave 3 (Time beyond 5 years)

1. At scale EV charging network
2. Carbon capture, utilization, and storage
3. Fuel switching at refineries and logistics

Adoption post technology maturity, cost curve evolution, and evolution of stable industry standards

Financing the Transformation

Weaning Asia off carbon will require some $26tm-37tm in investment between now and 2050, estimates the Asia Investor Group on Climate Change, a club of business types. Grants and subsidies from rich countries will be needed to spur private investment. India's prime minister, Narendra Modi, has named his price for agreeing to net zero: $ltm in funding by 2030 alone (Economist, 2022).Yet not all projects will be commercially viable. What India is asking for is ten times the annual amount promised to all poor countries under the Paris agreement of 2015, little of which has so far been disbursed so far. Challenge for oil industry would be to find funds for very large-scale capital investments with much diminished rates of return. Leadership of the companies will be under watch how can they protect both planet and dividend. Mother of challenges for political leadership of India would be to deliver the news and act that coal would not be of any use beyond in next 30 to years to population of 250 million living in coal dependent rather impoverished states of West Bengal, Odisha, Madhya Pradesh and Jharkhand (Economist, Even by the standards of poor countries, India is alarmingly filthy, 2018). As we notice it is not part of any election manifesto or political rallies.

Conclusion

Challenge for oil industry of India is unique in its own sense. World is talking about a utopia of NET ZERO world which many are skeptical about considering humanity's past record. In case of India, demand for hydrocarbon is expected to rise till 2040 irrespective of scenarios even if India get completely committed to Zero Emission. As large part of existing businesses of downstream oil, industry will disappear by 2060 or so. How companies would do the transformation without gutting the balance sheet is a billion-dollar question as they stare at the barrel. Lest Oil, Gas and Energy companies not forget in haste that however pensioners love Net Zero world but their love for dividends is too overpowering to forego. Shell realized it in 2020 when they cut it for the first time since Second World War.

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Role of Energy Data in Energy Security Planning

06

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Given the importance of energy security and energy transition at the global and national level, a robust, consistent and reliable energy data can help understand the energy profile of a country. An energy statistic is vital to trace the flow of different forms of energy in a country. It helps provide a true picture of how energy has been used in a country. To understand the consumer market for a country, one must be aware of the country's fuel security and perform a detailed study on the data set comprising fuel consumption corresponding to different sectors of end use. It forms the basis to develop indicators for each energy product's role in a country's economy.

Reliable and consistent energy data facilitates in assessing the effect of various policies. In the contemporary times where energy transition holds high priority, robust energy data can help policy makers formulate data backed policies. Analysis provides an efficient energy planning to harness the nuances of the data produced

within the various energy sectors and employ it more beneficially. While logging the data we must be careful to Data redundancy, which may increase the size and complexity of a database making it more of a challenge to maintain. Data more than required is just a garbage. Paper has also discussed Characteristics of data quality wrt Accuracy, Completeness, Reliability, Timeliness, Relevance, and Availability.

Key words: CO2, NDCs, GDP, ROI, CoP21, CoP26

Climate change is one of the most challenging phenomena being faced by the humanity and India has been at the forefront of addressing this issue. India ratified the Paris Agreement in 2016 under which its member countries have given commitments to keep the global average temperature rise between 1.5-2 degree C by the mid of this century.

India in its updated Nationally Determined Contributions (NDCs) has committed that it will reduce the emission intensity of its GDP by 45% by 2030 from 2005 level. Further, it has proposed to install 50% of the power capacity from non-fossil energy sources and aim to achieve net zero emissions by 2070.

With a population of 1.4 billion, India has a massive demand for energy to fuel its rapidly growing economy. From a power deficit nation at the time of Independence, the efforts to make India energy-independent have continued for over many decades. Industrial investments in clean energy sources and enhancing energy efficiency are hailed as two of the most viable options for any country's decarbonization efforts, at any level of development. Today, India is a power surplus nation with a total installed capacity of over 400 GW. Keeping in mind the sustainable development goals, India's power generation mix is rapidly shifting towards renewable energy. India is the world's third largest producer of renewable energy, with over 40% of its installed electricity capacity coming from non-fossil fuel sources. At this stage, India needs a structured approach to develop a matrix of growth of all forms of Energy to achieve the Energy Security and fulfil the promise given to this Earth.

Given the importance of energy security and energy transition at the global and national level, a robust, consistent and reliable energy data can help understand the energy profile of a country. An energy statistic is vital to trace the flow of different forms of energy in a country. It helps provide a true picture of how energy has been used in a country. To understand the consumer market for a country, one must be aware of the country's fuel security and perform a detailed study on the data set comprising fuel consumption corresponding to different sectors of end use. It forms the basis to develop indicators for each energy product's role in a country's economy.

Reliable and consistent energy data facilitates in assessing the effect of various policies. In the contemporary times where energy transition holds high priority, robust energy data can help policy makers formulate data backed policies. Along with facilitating in the estimation of CO2 emissions with respect to the national territory, energy data can also be used as an input for modelling and forecasting.

Therefore, to give a holistic picture of a country's energy sector and course correction to a sustainable path of development, compiling and dissemination of energy data is important.

Given the importance of energy access, energy security and energy transition at the global and national level, a robust, consistent and reliable energy data can help understand the energy profile of a country. It also helps in assessing the impact of various policies and programmes. In contemporary times where energy transition holds high priority, robust energy data can help policy makers formulate data backed policies that would support countries to achieve its environmental and developmental commitment in the coming years.

What are energy data analytics?

Energy data analytics is the real-time response to oscillating market fluctuations, allowing for a more comprehensive and responsive overview of the utilities sector.

1. Track health and environmental milestones at every step.
2. Enhance business decisions based on energy market forecasts.
3. Reduce downtime and improve worker safety and productivity.
4. Systematically predict changes in marketplace demand.
5. Balance resources and asset integrity without compromising cost.

Benefits of Data Analysis

Energy analytics is the process of gathering data with the help of software in order to assist energy suppliers to analyse, supervise, and optimize energy related KPIs like production costs, consumption, production distribution, and many others. Numerous kinds of energy are powering our industries, businesses and day-to-day lives. Analysis provides an efficient energy planning to harness the nuances of the data produced within the various energy sectors and employ it more beneficially. This improves profit margins as well as manipulate and understand large-scale trends in the industry. Applying data analytics to the energy sector provides a deeper insight across all the dimensions of that sector, so as to treat it as the commodity, which it actually is.

- Realtime Credible data enable a better understanding of the energy profile of various sectors, subsectors and consumer groups.
- The analysis provides an overview of the impact of various policies on energy savings and CO_2 emission reduction with corresponding monetary savings.
- Fluctuation in Energy requirements in future.
- Planning of fuel switch required in various sector.
- The information provided in this report will help in assessing the status of data availability of various energy products in the country.
- It can also help in analysing energy intensity of the country thereby enabling policy makers to formulate robust policies and carry out course corrections.

- Using energy analytics data more effectively will help you solve complex problems, and at the same time improve from traditional technologies.

What are the disadvantages of data redundancy?

Data redundancy may increase the size and complexity of a database making it more of a challenge to maintain. A larger database can also lead to longer load times and a great deal of headaches and frustrations for employees, as they will need to spend more time completing daily tasks. Any data more than required is garbage as saying goes if you process garbage output shall be garbage only.

Characteristics of data quality

1. **Accuracy** : First and most important is data accuracy. Least count & calibration of data logger must be UpToDate so that reproducibility is ensured. Frequently data logged must be logically checked and re-checked.
2. **Completeness**:Often when you are using consumer data, it is not quite complete. Unfortunately, if information is missing, or if there are a lot of gaps that you have to try to pull together yourself, data is not considered high quality.
3. Reliability: Another factor in determining data quality is whether it is reliable or not. However, what does this mean exactly? A lot of data contradicts other data you may have, and it is hard to know which information is correct. This is not reliable data, and that makes your job more confusing and ambiguous.
4. **Timeliness**: There is a lot of data out there that has not been updated. If a lead moves, their old address may be useless to you. If a consumer was shopping for a specific item weeks ago, your messages will not land as they could have in the moment. Outdated or obsolete information is poor-quality data.
5. **Relevance**: It is important to note that even if data is accurate, it may not be applicable to what you are trying to do. When you gather a lot of irrelevant information about consumers, you are wasting time and energy on data that you do not really need, and that actually you are generating garbage.
6. **Availability**:Finally, data must be available in order to be useful and high quality. People within the organization must be able to access the data they need to do their jobs. Information should be stored in a place where everyone who requires it can see it in a manageable format, like a simple dashboard that includes summaries, analysis, and graphs.

Conclusion

Energy data analysis also lead to Energy efficiency that can bolster regional or national energy security. By reducing overall energy demand, efficiency can reduce reliance on imports of oil, gas and coal. Data analysis can also reduce the likelihood of supply interruptions.

Robust data analysis led to reduction in fossil energy imports in IEA countries and major emerging economies due to efficient data analysis since 2000.

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07

Role and Impact of Energy Data Organization on Energy Policy Development

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Introduction

Energy policy development plays a critical role in shaping the future of energy systems. These policies define the strategies, regulations, and goals necessary to ensure a sustainable, reliable, and affordable energy supply. However, effective energy policy development requires a solid foundation of accurate and comprehensive energy data. The organization and management of energy data are crucial in guiding policymakers and enabling evidence-based decision-making (Patlitzianas et al., 2008). Every nation has its unique set of energy policy goals. Nevertheless, in response to the challenges posed by climate change, numerous countries are actively striving to shift their energy systems towards greater sustainability (Harichandan et al., 2022).

Consequently, monitoring the progress of energy transitions has gained significant importance for governments, as they aim to establish and achieve their targets. In the pursuit of monitoring clean energy transitions, various policy domains can be recognized. These policy domains include: (a) tracking target indicators of Sustainable Development Goals (SDG 7), (b) Design and implement sectoral policies like for industries, transportation, constructions, energy, and power sector etc., ensure energy security (accessibility, availability, and affordability), fulfilment of Nationally Determined Contributions (NDCs) related to energy and have a track over the greenhouse gas emissions (IEA, 2022). The mentioned policy domains employ a combination of individual indicators, such as the Sustainable Development Goals (SDGs), and comprehensive datasets like energy balance and greenhouse gas (GHG) inventories, to facilitate government analysis and inform policy decisions. These data sources enable policymakers to establish a baseline and monitor the advancements made in specific policy initiatives. Since the bulk of essential energy information is derived from the fundamental energy data collection, any investment made in data directly contributes to the effectiveness of the policies themselves.

This article explores the impact of energy data organization on energy policy development, highlighting the challenges, benefits, and best practices for utilizing energy data effectively.

The Role of Energy Data in Policy Development

Energy data serves as the backbone for sound policy development. It provides policymakers with critical insights into energy supply, demand, and consumption patterns, helping them understand the current energy landscape and identify areas for improvement. By analysing energy data, policymakers can formulate informed policies that address energy security, environmental sustainability, and economic considerations.

Energy data informs policymakers about the availability and reliability of various energy sources. It helps them understand the geopolitical implications of energy imports and exports, assess the potential risks associated with energy supply disruptions, and develop strategies to diversify energy sources and reduce dependence on specific regions or fuels.

Moreover, energy data provides policymakers with valuable information about energy consumption patterns. It allows them to identify energy-intensive sectors, understand the factors driving energy demand growth, and develop policies to promote energy efficiency and conservation. By analysing energy data, policymakers can also identify regional disparities in energy access, affordability, and reliability, and design policies that address these disparities (Kar and Harichandan, 2022). Due to the intricacy of contemporary systems, it is impractical to manually carry out the analysis. Employing modelling techniques enables policymakers, analysts, and statisticians to utilize data for scenario analysis, enabling them to evaluate the effects of various alternatives (Kaya et al., 2019). Subsequently, this information

Figure 1

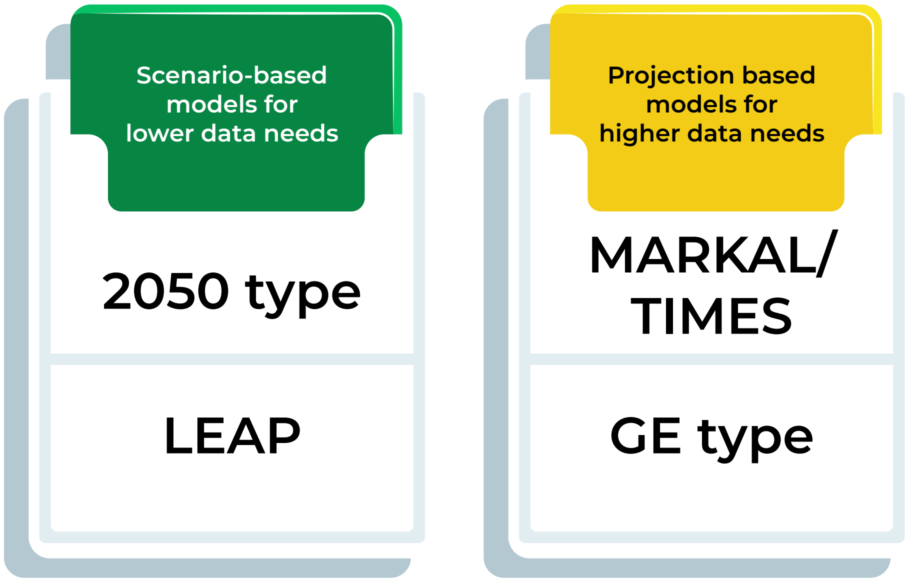
Steps involved in energy data modelling process

can be utilized to shape and guide objective-oriented policies and strategies. Nevertheless, modelling should not be perceived as a mere mechanical process of input and output. To minimize uncertainty and maximize the effectiveness of the outcomes, several preparatory and follow-up steps as highlighted in fig.1 are essential in conjunction with the actual modelling process.

Energy data modelling plays a crucial role in assessing the environmental impact of energy systems. It enables policymakers to track greenhouse gas emissions, evaluate the effectiveness of existing policies and measures to mitigate climate change, and design strategies to transition to cleaner and more sustainable energy sources. In general, as suggested by IEA (2022) widely used models can be categorized into four types: general equilibrium (GE) models, MARKAL/TIMES models, LEAP models, and 2050-type calculators. Fig.2 illustrates the distinctions among these models based on the needs of the researchers. Scenario-based needs in data modelling refer to the requirement of incorporating various hypothetical scenarios or alternative futures into the modelling process. This involves creating different sets of assumptions, inputs, and conditions to analyse the potential outcomes or impacts under different circumstances. Projection-based needs in data modelling refer to the requirement of making future predictions or projections based on historical data and trends (Kannan et al., 2015). This involves using statistical techniques and modelling approaches to forecast the potential outcomes or trends for a given system or phenomenon.

Figure 2

Prominent energy models used by policy researchers



Challenges in Energy Data Organization

Despite the importance of energy data, several challenges hinder its effective organization and utilization in policy development. These challenges include:

Data fragmentation

Energy data often originates from various sources, including government agencies, utilities, research institutions, and private entities. Fragmentation of data across multiple platforms, formats, and accessibility levels makes it difficult to consolidate and analyse the information coherently. Different organizations may use different data collection methods, definitions, and reporting formats, leading to inconsistencies and challenges in comparing and integrating data from various sources.

To address data fragmentation, policymakers need to establish mechanisms for data coordination, collaboration, and harmonization. This can involve developing standardized data reporting formats, aligning data collection methodologies, and encouraging data sharing and exchange among different stakeholders. International organizations and initiatives can play a crucial role in facilitating data harmonization and collaboration across borders.

Data quality and accuracy

Ensuring the quality and accuracy of energy data is crucial for making informed policy decisions. Incomplete, outdated, or inconsistent data can lead to flawed analysis and misguided policies. Data validation, standardization, and quality assurance processes are necessary to address these issues.

Policymakers should establish rigorous data quality control mechanisms to ensure that the data used for policy development is reliable, consistent, and up to date. This can involve setting clear guidelines for data collection, establishing data quality assurance protocols, and conducting regular audits and reviews of energy data. Collaboration with data providers, such as utilities and research institutions, can help improve data accuracy and reliability.

Data accessibility and sharing

Limited accessibility to energy data can hinder effective policy development. Data sharing and collaboration among stakeholders, including governments, research institutions, and industry, are essential to promote transparency, enhance analysis capabilities, and encourage innovation.

Policymakers should strive to enhance data accessibility by implementing open data policies and initiatives. Open data policies ensure that energy data is made available to the public, researchers, and businesses in a timely and accessible manner. Governments can create centralized platforms or data portals where energy data is openly shared, allowing users to access, analyse, and utilize the data for research, innovation, and policy development purposes. However, it is essential to balance data accessibility with privacy and security concerns, ensuring that sensitive information is appropriately protected.

Data integration

Integrating data from multiple sources is often challenging due to varying data formats, structures, and incompatible systems. Establishing data integration frameworks and standards can facilitate the seamless aggregation and analysis of energy data.

To address data integration challenges, policymakers should adopt data integration platforms or frameworks that allow for the efficient collection, storage, and analysis of energy data. These platforms should support interoperability, enabling different data sources and systems to communicate and exchange information effectively. Common data standards and formats should be established to ensure compatibility and consistency across datasets. Additionally, policymakers can encourage the development of application programming interfaces (APIs) that enable seamless data integration and exchange between different energy data systems.

Benefits of Effective Energy Data Organization

Efficient organization of energy data can yield numerous benefits for energy policy development:

Informed decision-making

Well-organized and accessible energy data enables policymakers to make evidence-based decisions, considering the real-world implications of various policy options. It provides policymakers with a comprehensive understanding of the energy sector, its challenges, and opportunities, enabling them to develop policies that are grounded in data-driven insights. By leveraging accurate and reliable data, policymakers can evaluate the potential impacts of different policy measures, assess their feasibility, and choose the most effective options.

Targeted policy formulation Energy data provides insights into energy consumption patterns, regional disparities, and emerging trends, allowing policymakers to develop targeted policies that address specific challenges and opportunities within the energy sector. For example, by analysing energy consumption data, policymakers can identify sectors with high energy demand and design energy efficiency programs or incentives to reduce energy consumption in those sectors. Similarly, energy data can help policymakers identify regions with limited access to clean energy sources and design policies to promote renewable energy deployment in those areas.

Monitoring and evaluation

Properly organized energy data allows policymakers to monitor the effectiveness of implemented policies, assess their impact, and make necessary adjustments in a timely manner. By tracking energy indicators and performance metrics, policymakers can evaluate the progress made toward achieving policy goals and targets. This monitoring and evaluation process helps identify areas where policies are successful and areas that require further attention or modification. Regular assessment of policy outcomes allows policymakers to learn from past experiences and improve future policy design.

Stakeholder engagement

Energy data can facilitate meaningful engagement and collaboration with stakeholders, including industry, academia, and civil society. Sharing relevant data with stakeholders fosters transparency, builds trust, and encourages their involvement in policy development processes. By involving a wide range of stakeholders in energy data collection, analysis, and interpretation, policymakers can benefit from diverse perspectives, insights, and expertise. This collaborative approach ensures that policies are more inclusive, responsive to stakeholder needs, and aligned with the broader goals of society.

Best Practices for Energy Data Organization

To maximize the impact of energy data on policy development, certain best practices should be followed:

Data standardization

Establishing common data standards and formats ensures consistency and compatibility across different datasets. Adhering to international standards, such as the Energy Information Administration's (EIA) Data Standards, promotes interoperability and simplifies data integration processes. Standardized data formats also facilitate data exchange and sharing among different stakeholders, enabling efficient collaboration and analysis.

Open data initiatives:

Governments should embrace open data initiatives to enhance data accessibility and transparency. Open data policies allow researchers, businesses, and the public to access, use, and analyse energy data, promoting innovation and fostering collaboration. By making energy data openly available, governments can leverage the expertise and insights of a broader range of stakeholders, leading to more robust and effective policy development.

Data governance

Developing robust data governance frameworks ensures data privacy, security, and compliance. Establishing clear guidelines on data ownership, sharing, and usage rights facilitates trust among data contributors and users. Data governance frameworks should also address issues related to data protection, confidentiality, and ethical considerations. By implementing strong data governance mechanisms, policymakers can build confidence in the energy data ecosystem and ensure the responsible and ethical use of data.

Data integration platforms:

Implementing data integration platforms or centralized databases can streamline data collection, management, and analysis processes. These platforms should support efficient data sharing and collaboration among stakeholders. Data integration platforms enable seamless data aggregation, standardization, and analysis, reducing the time and effort required for data management tasks. By centralizing energy data in one platform, policymakers can improve data accessibility and facilitate data exchange across different sectors and organizations.

Data analytics and visualization:

Utilizing advanced analytics tools and visualization techniques helps policymakers derive actionable insights from energy data. Interactive dashboards, visual representations, and predictive modelling enable policymakers to explore various scenarios and assess the potential impact of different policy options. Data analytics allows policymakers to identify trends, patterns, and correlations in energy data, enabling evidence-based decision-making. Visualizing data through charts, graphs, and maps enhances policymakers' understanding of complex energy systems and helps communicate key findings to diverse audiences. For example, Petroleum Planning and Analysis Cell provides deeper insights on petroleum products demand and consumption, which are extremely useful for policymakers and industries.

Conclusion

The effective organization of energy data plays a crucial role in energy policy development. Overcoming the challenges associated with data fragmentation, quality, accessibility, and integration is essential for leveraging the full potential of energy data. By implementing best practices in data organization and management, policymakers can make informed decisions, formulate targeted policies, and monitor their effectiveness. A robust energy data infrastructure, combined with stakeholder engagement, can pave the way for a sustainable, secure, and efficient energy future.

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08

Fuelling the Energy Future: The Power of Data and Information

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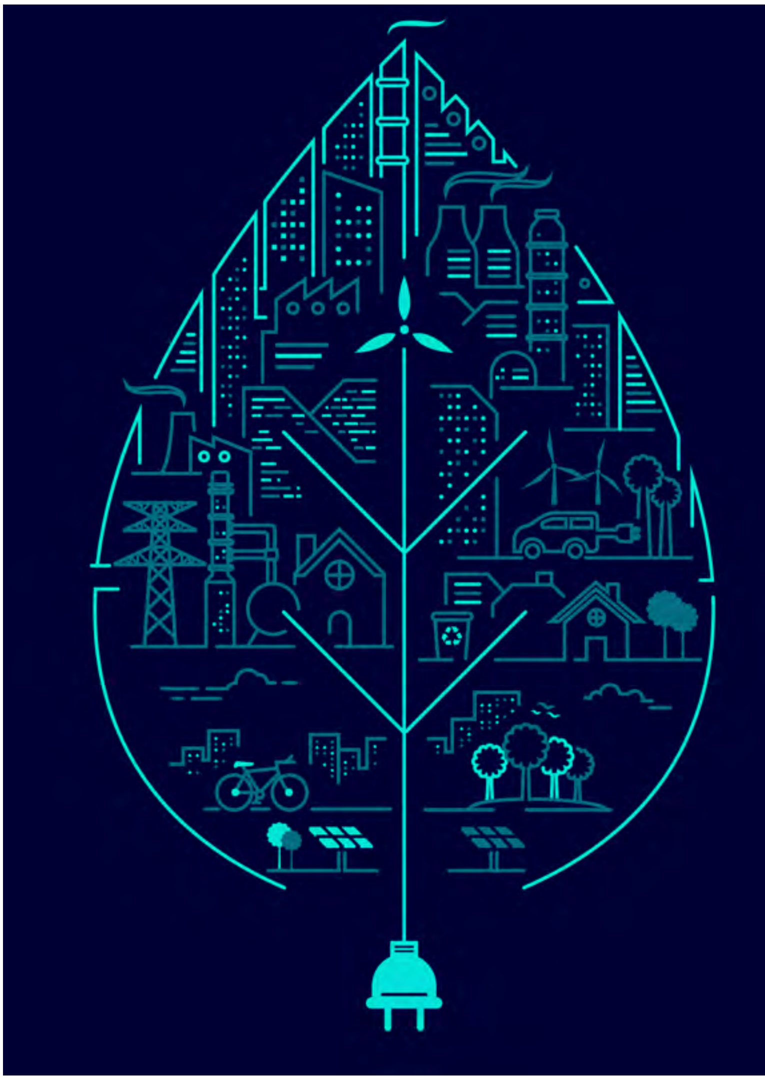
Role and Importance of Data in Enabling Energy Transition

As it goes, 'Data is information and information is power"- The power to predict energy demand and consumption patterns, the ability to plan supply-side alternatives and finally be able to impact lifestyles. This not just opens a plethora of opportunities but carries with it immense responsibility. In line with this, geographies across the globe are striving towards reducing greenhouse gas (GHG) emissions and combating climate change. At the same time, advanced technologies, new policies and markets are re-defining the way we consume and produce energy. The need to move away from conventional fossil fuels to renewable energy has kickstarted a new wave of energy transformation. However, in the

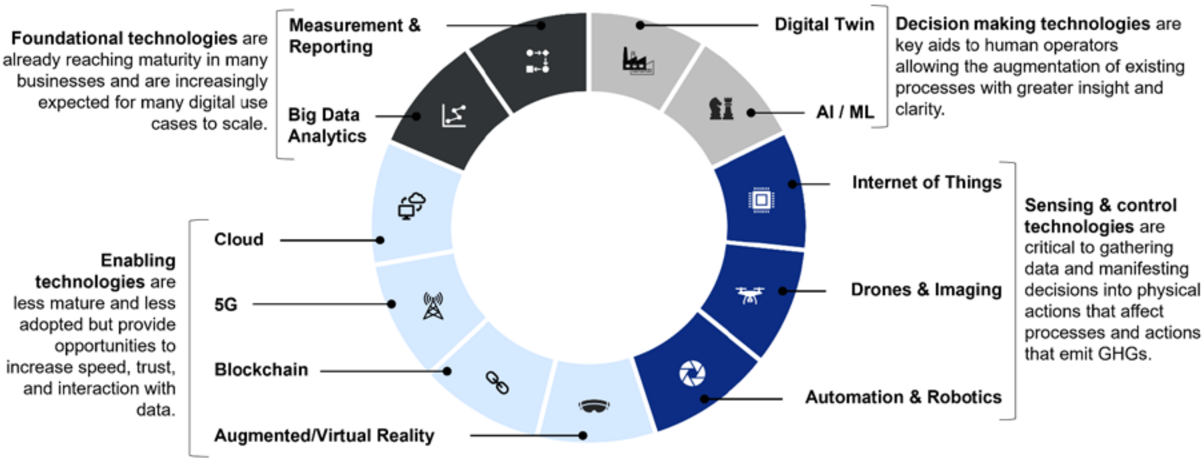


development of transition pathways, data is very crucial and requires a paradigm shift in how we collect store and use data.

This is because it is the data that can help us shape and drive Climate Resilient Trends, which can be defined as the mega-trends that are large-scale, long-term, low-carbon & sustainable that together impact various facets of the environment, economy, society, technology and geopolitics. These emerging trends would require systematic integration of data and technology for building smart cities, deep decarbonization of hard-to-abate industries, sustainable cooling solutions for buildings, effective weather forecasting for enhancing crop productivity, robust modelling assessments for building energy supply chains etc. Such trends when superimposed with the four clusters of digital technologies (Figure 1) as mentioned below can lead to long-lasting impacts and solutions for our planet.

Figure 1

The cluster of Digital technologies



Weaving a New Data Regime: Global Efforts

In recent years, the significance of data availability and transparency have emerged as critical pillars for evidence-based decision-making and promoting holistic approaches for a sustainable future. Countries and organizations worldwide are recognizing the importance of open access to data. Government bodies and various institutes, including financial and autonomous organizations, are continuously enhancing their data collection and reporting methods.

In accordance with various international reporting requirements for developed countries such as UNFCCC amongst others, a set template for data compilation, collation, monitoring, tracking and reporting of actions has been provided. These templates can be adapted globally. However, it is essential to recognize that while the developed countries have achieved a commendable level of data availability, developing nations are persistently striving to bridge the basic gap due to limited resources, insufficient infrastructure and technology, and various socio-economic challenges. Despite these constraints, many developing nations have recognized the pivotal role of data in their progress and have initiated far-reaching endeavours to harness information for their development agendas. There are already existing data dashboards and portals maintained publicly and privately which serve as prime examples of data banks. These include Data and Statistics Portal by International Energy Agency, Databank by the World Bank, Our World in Data, WRI Datasets by the World Resources Institute, and Enerdata amongst others[ii]. These datasets offer comprehensive information for all countries worldwide.

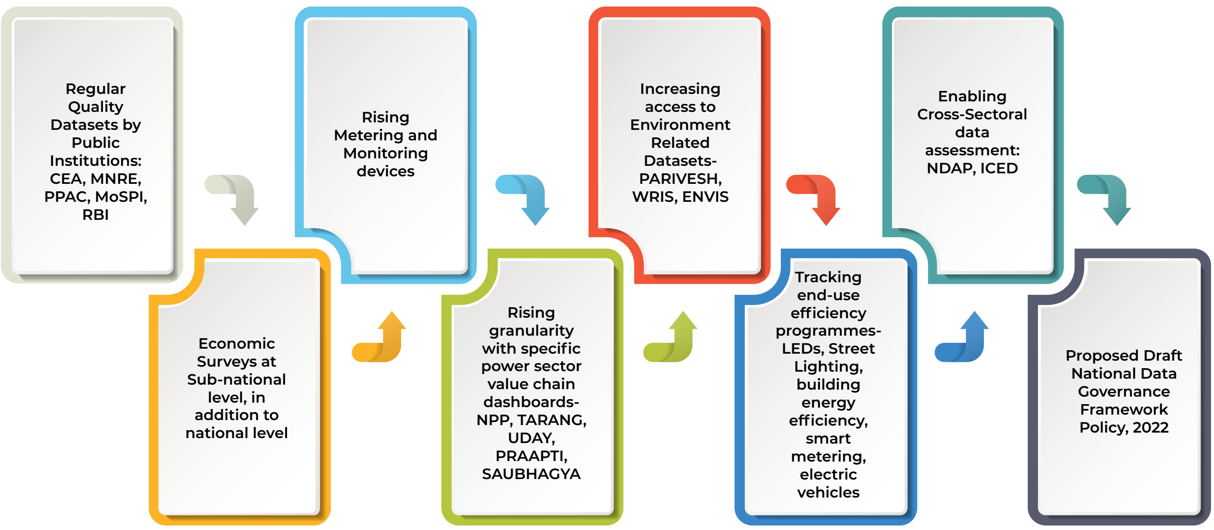
Specifically, data transparency in Asia requires improvement, as over half of the economies (24 out of 39) exhibit insufficient or poor data transparency[iii]. This lack of transparency further hinders understanding the electricity needs of almost 684 million people. Some of the challenges identified include the lag in publishing data, granularity of data both in time and space, data access etc. Notably, six economies, namely India, Sri Lanka, Bangladesh, South Korea, Australia, and New Zealand, stand out with 'good' or 'excellent' scores, showcasing commendable data transparency practices in the region.

India Leading a Data Revolution

In today's world, there's a well-known saying: "Data is the new Oil". This saying emphasizes the tremendous influence that data and its accessibility will have on both national and subnational economies. India has made remarkable progress in enhancing data availability and transparency in recent years (Figure 2). Each line ministry and department in the country maintains sector-specific data accessible to the public.

Figure 2

The Evolving Landscape of Energy Data Management in India



A comprehensive set of data covering the entire energy supply chain is readily available, encompassing details from reserves, production, consumption and prices. Additionally, the data on electricity generation, transmission, and distribution including sources of electricity generation and capacity data is updated timely. Nodal ministries on power, oil & gas, coal, renewable energy, energy efficiency, environment and water release these valuable datasets. However, all this data

Figure 3

Supply-side energy data inventory in India

Central Electricity Authority (CEA)

- Daily generation reports
- Monthly generation reports
- Installed capacity reports
- Transmission reports
- Power supply positions
- Renewable energy pipeline projects report
- General review report
- Fuel supply
- Thermal broad status report
- Hydro pipeline reports
- FGD status report
- Executive Summary report
- Electric Vehicle Charging Station /Power Consumption report
- Market Monitoring report
- Outstanding Dues report

Petroleum Planning & Analysis Cell (PPAC)

- Monthly Crude oil, petroleum products and Natural gas production reports
- Monthly petroleum products and Natural gas consumption report
- Monthly petroleum products and Natural gas Import/Export reports
- Daily Retail Selling Prices
- Monthly report on Indigenous crude oil production, crude oil import, & processing
- City Gas Distribution Network, Existing Pipeline Structute
- Subsidy/Prices reports
- Snapshot of India's Oil & Gas data Monthly Ready Reckoner
- Forecast and Analysis reports

GRID Controller of India (POSOCO)

- Daily demand and electricity met
- Monthly peak demand and electricity supply report
- RRAS providers details

Ministry of Petroleum and Natural Gas (MoPnG)

- Monthly production reports
- Indian PNG statistics
- Annual report of Directorate General of Hydrocarbons

Ministry of Statistics and Programme Implementation (MOSPI)

- Energy Statistics report
- Environment Statistics (EnviStats)
- National Accounts Data
- National Statistical Office (NSO) reports
- National Sample Survey Reports
- Social Statistics, and Economic Statistical reports
- Periodic Labour Force Survey (PLFS)
- Annual Survey of Industries and Consumer Price Indices reports
- Annual Reports and other research & publication

Reserve Bank of India (RBI)

- Database on Indian Economy
- Handbook of Statistics on Indian Economy
- Annual Reports
- Data Releases Report

Ministry of New and Renewable Energy (MNRE)

- Physical progress report
- Akshay Urja Portal
- Annual reports

Ministry of Coal (MOC)

- Monthly Statistical report
- Coal directory of India
- Annual report
- Koyla Darpan Dashboard

Ministry of Environment, Forest and Climate Change (MoEFCC)

- Biennial Update Reports (BURs)
- National Communications (NATCOMS)
- Forest Survey of India
- ENVIS Centre on Wildlife & Protected Areas
- PARIVESH portal

State Regulatory Commissions/ Distribution Companies

- Tariff Orders
- Tariff Petitions
- Annual Reports/Accounts
- Power Purchase Agreements

exists in numerous portals, dashboards, and reports, each managed by different ministries and departments. Figure 3 provides an in-depth data inventory for all the supply-side energy data in India.

NITI Aayog, a premier policy think tank of the country has been launching numerous initiatives to enable cross-sectoral and holistic data availability for the masses. The National Data and Analytics Platform (NDAP)[iv] launched in May 2022 provides macro-datasets across a whole array of sectors such as Energy, Agriculture, Consumer Affairs, Tourism, Education etc. To further advance the data mining efforts for India's energy transition, NITI Aayog, launched the India Climate and Energy Dashboard (ICED)[v] in July 2023, in partnership with Vasudha Foundation. This one-of-a-kind user-friendly platform integrates comprehensive, granular, historical, and near real-time data to provide single window access data to the users. ICED provides data and information on India's energy, climate, and relevant economic aspects which empowers policymakers, researchers, and energy companies to gain unprecedented insights into the dynamics of energy systems. ICED serves as a testament to India's commitment to advancing clean energy initiatives.

In recent times, several instances have emerged in India where the presence of high-quality data has steered the path towards a clean energy transition. Some cases are as follows:

Robust policy and regulatory mechanisms for addressing air quality in India:

Increased penetration of air quality monitors across India has led to policy/s being formulated at the national and sub-national levels to address air quality. The air quality monitors have helped immensely in identifying the sources of pollution which in turn has helped in developing appropriate implementation plans for addressing air quality. To put this in perspective, India now has a total of 1216[vi] air quality monitoring stations (883 national air quality monitors, 333 continuous ambient air quality monitoring stations) that have been put in place till 2021 covering 378 cities/towns in 28 states and six union territories. As accurate and real-time data on pollutants and their sources become more accessible on a large scale, local government authorities are responding with stringent policy measures. They are revising emission norms for polluting sectors, imposing restrictions on construction activities, and implementing penalties to deter agro waste burning.

Better forecasting of Variable Renewable Energy (VRE) generation:

Accurate forecasts of solar irradiance, wind speed, temperature etc. through satellite image-based information and advanced machine learning algorithms have significantly reduced the forecasting error of renewable generation profiles in India. Further, the Numerical Weather Prediction (NWP) models[vii] are proven to be far more accurate for day-ahead forecasting. With accurate and real-time data, these models can reliably forecast the variable renewable energy (VRE) generation, hence allowing for better integration of solar, wind, and other clean sources into the grid. This has helped in creating appropriate policies as well as boosting investor confidence.

Monitoring of electricity consumption patterns for demand-side planning:

The Government of India is implementing a phased plan to install 250 million smart meters by the end of the year 2025[viii]. These smart meters and real-time energy monitoring tools allow individual consumers and businesses to track their daily/hourly energy usage, identify areas of improvement, and make informed choices to reduce their carbon footprint. Further, these smart meters will allow distribution companies to identify the areas which could help them to mitigate the peak hour challenge by various peak shaving/shifting solutions.

Enhancing optimization of grid operations:

Introducing a web-based automated power scheduling and a tracking system by POSOCO has significantly enhanced the optimization of India's electricity grid. Data driven insights help in providing enhanced transparency and reliability along with cost savings. As an example, it helped in the implementation of the Security Constrained Economic Dispatch (SCED) pilot[ix].

Accessing quality data: Miles to go

Data-supported systems can empower policymakers, businesses and consumers to make informed decisions and make energy choices that are clean, sustainable and affordable. However, the success of data-driven decision-making depends on the quality of data. Further, data quality is not unidimensional, but a multi-dimensional concept[x]. Different studies[xi][xii][xiii]suggest multiple attributes of data quality starting from accuracy, reliability, precisions to completeness, timeliness, volume, security etc. as important dimensions of data quality. Hence, there is a need to evaluate the quality of data for a particular task and set logical boundaries for the criteria for data.

While the benefits of high-quality data for fast-tracking our 2070 net zero goals cannot be understated, it is paramount to bridge the challenges to access the same. The four pillars of building a strong data regime rest on four broad pillars: Data Availability/Access, Data Collection, Data Management and Data Analysis[xiv]. We discuss below a set of few examples where data discrepancies are hindering the overall decarbonizing policy narrative in India.

Data Availability/Access:

This data attribute brings together aspects of non-availability of data within the energy and climate sector and hence results in limited or no assessments with respect to them. Another aspect of this is the limited access to data, owing to its security and privacy. Presented below are two examples where data availability has been a challenge for years.

1. **Deciphering demand-side data**: For years, disaggregated energy demand-side data has been a challenge. While there has been some progress made by assessing energy consumption at sectoral levels such as buildings, industry, and transport levels (mostly from the energy balance) at the national level; there is limited data availability to understand activity and efficiency of the demand-side such as air conditioning load, fuel usage by a vehicle category, number of five-star appliances in a household etc. The ability to capture real-time and granular data for understanding end-use consumption patterns has remained weak because it is difficult to gather this data and there is insufficient mechanism for address this barrier. This has resulted in poor baseline and measurement and

verification frameworks which have further hindered India's efforts to deploy energy efficiency and demand-side management programs at their full potential and scale.

2. **Tracking Climate Finance Flows**: The clarion call for Net Zero has ramped up the need for green and sustainable finance for engaging in environmentally sustainable activities. As estimated, India will need an average of USD 160-170 billion per year till 2030 to meet it said Nationally Determined Contribution (NDC) targets[xv]. This is almost four times the current green finance flows of USD 44 billion/year[xvi] for India as reported for 2019-20. This enhanced mobilization of finance needs credible tracking and reporting of green finance data to monitor fund flows and further attract increased capital. However, the availability of data for tracking finance flows from both public and private sectors remains unsatisfactory; both in terms of its quality and granularity. For example, it is crucial to get project-level data on a monthly basis to track yearly investment flows. This is because a large number of commitments are made for multiple years and there is a need for tracking of disbursements against the commitments[xvii]. Moreover, the lack of a green finance taxonomy poses additional challenges and increases the risk of 'greenwashing'. To this end, the Reserve Bank of India (RBI) recently released a framework to boost the green finance ecosystem in India.

Data Collection:

This data attribute refers to the process of information gathering and accessing multiple datasets. The choice of data collection is largely dependent on the following: availability of technology, human and financial resources. Traditionally a combination of four major methodologies have been applied to garner this information – government sources, surveys, metering and modelling[xviii]. However, the advancement of new technologies such as smart devices and sensors, connected devices, cloud computing, web scraping etc., has led to exploring faster and automated ways for large-scale data collection and storage. Presented below are two examples that deploy traditional data collection methods and face data granularity issues:

1. **Consumer level data for distribution companies to inform cost-reflective tariffs, better asset planning, and demand assessments**: Though the Electricity Act 2003, directs to reduce the cross-subsidization of electricity tariff and subsequently Tariff Policy 2006 has directed to keep the cross-subsidies within the range of 20% of the average cost of supply, still many states have higher variation in retail tariffs across the consumer categories. This could be largely attributed to the data unavailability owing to the absence of meters at various feeders and distribution transformers.
2. **Subnational, district and city level data for localizing climate action**: It goes without saying that actual net zero achievements are not just limited to the national level but further lie at the sub-national and local levels. In order to develop such robust net zero plans, granular data for the sub-national levels across all

parameters is critical. While India has made substantial progress in compiling and collating the data for a few sectors, several data gaps continue to exist. One example is the data from the Micro, Small and Medium Enterprises (MSME) sector. Further, in addition to addressing gaps the requirement is to have real-time quality data. Nonetheless, there are a few non-government initiatives such as GHG- Platform India[xix], SMoG-India[xx] etc. amongst others that could serve as ready templates to boost India's journey for localizing climate action.

Data Management:

This data attribute refers to the most critical stage where data is transformed and structured into formats most suitable for analysis. This includes steps on data aggregation, cleaning, standardization and imputation.

Data formats present significant challenges in the realm of data management and analysis. There are examples of diverse and complex data formats, including scanned PDFs, complex Excel sheets, and varying formats for identical parameters across different states. The process of converting data from one format to another is both complex and time-consuming, often leading to data loss or inaccuracies. Addressing these challenges is of utmost importance to fully unleash the potential of data-driven insights and innovation in today's digital landscape. For example:

1. **Discoms operational and financial statistics**: Data standardization poses challenges due to variations in assumptions, calculations and classifications. These challenges are evident in the data of distribution companies. For instance, there are variations in calculation methodologies for losses, consumer category classifications, financial analysis, and the determination of cost of supply, which leads to inaccurate insights for similar/different DISCOMs and states. It is important to bring all the data to a common scale to ensure fair comparisons and reliable analysis for DISCOMs' operations and working.
2. **Varying Irrigation statistics**: In India, irrigation of farmland is being carried out by various means such as ground-water pumping, canal and river water pumping, and natural irrigation through rain. For pump-based irrigation, the data of pumps varies a lot in different statistical reports. For example, the number of diesel pump sets varies in various reports such as Agricultural Census; Input Survey and Minor Irrigation Census reports[xxi]. The inconsistency in data impacts the overall decision-making, analysis, and data integrity.

Data Analysis [xxii]:

The need for data is to deliver meaningful insights, analysis and inferences. This data attribute deploys numerous analytical and statistical tools to understand different datasets[xiii]. Some of the methods for analysing data include Regression Analysis, Cluster Analysis, Time-series Analysis, Sentiment Analysis etc. Similarly, a combination of the tools could be deployed such as Microsoft Excel, Python, Tableau, and R, amongst others. Regular and robust analysis can enable evidence-based policy formulations, sustainable resource use and the building of an efficient economy.

Way Forward

The proposed Draft National Data Governance Framework Policy, May 2022[xxiv] aims to bring drastic changes in how we access, collect and use data. It envisions setting up a much-needed 'India Data Management Office (IDMO)' that shall formulate all data/datasets/metadata rules, standards, and guidelines in consultation with Ministries, State Governments, and Industry. While the policy is still in draft stages, it needs to be considered that energy data management in India is fairly decentralized. As we observed in Figure 3, multiple ministries, departments and offices collect and publish energy-related data. Over the years, a strong supply-side repository has been created. However, demand-side data collection efforts have been limited. This is because demand-side data is dynamic and huge and requires dedicated technical and financial resources to implement it.

Two key strategies to build in a reliable energy demand side database are recommended: First, to embrace technology for faster and reliable data access. This is because conducting only sample and statistical surveys to understand end-use demand is both a costly, sub-optimal and time-intensive proposition. This needs to be augmented with new business models to improve energy metering and monitoring infrastructure and further support it with new digitalization technologies on machine learning, cloud computing, GPS etc. to minimize errors. Second, improved coordination and participation from all sets of stakeholders such as Municipalities, Panchayati Raj Institutions, Not-for-Profits, Industry etc. is key to gaining access to comprehensive ground-level data. Traditionally, on the supply side, the data flow has been unidirectional, where data from power plants, electricity meters or monitoring systems were recorded and processed. However, as we move towards more decentralized energy systems, the two-way flow of data whether it is from rooftop-solar photovoltaics or charging infrastructure or smart controlled devices, all will support in building crucial qualitative inputs on user-behaviour, performance, preferences etc. A participatory approach with periodic surveys, workshops, and capacity building can go a long way in building a robust

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09

Role of Natural Gas in India's Energy Strategy

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Gas Today

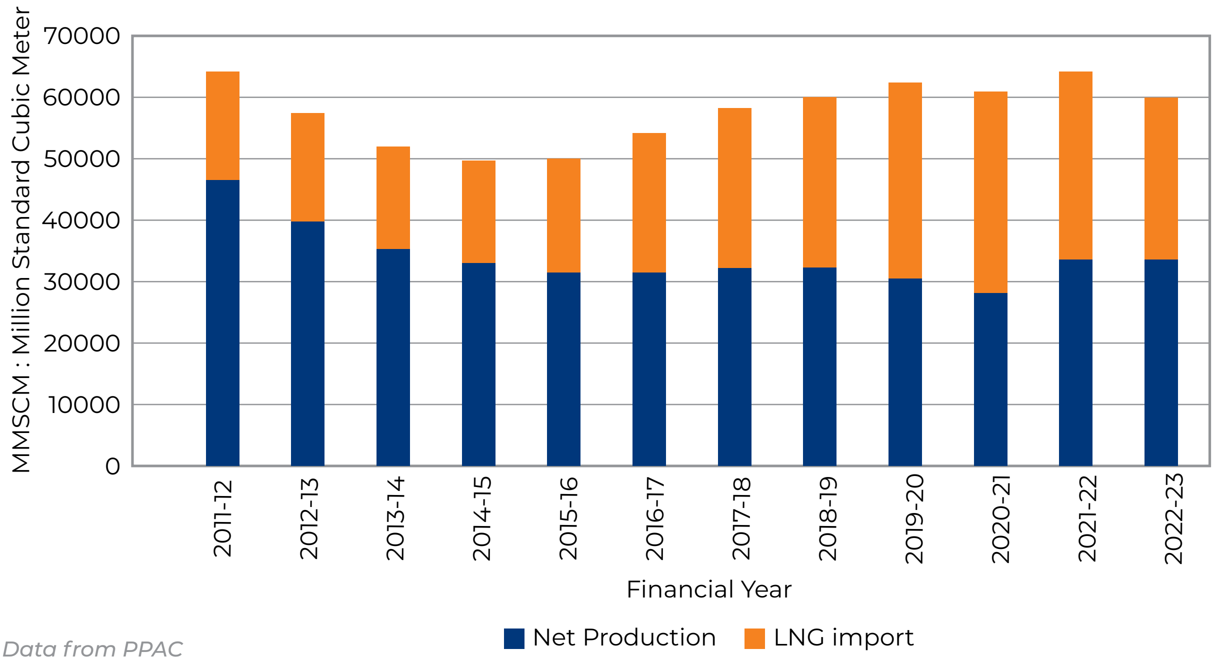
In 2021-22 India's total commercial energy consumption was 800 million tonnes of oil equivalent, mtoe. Natural gas constituted about 7% of the Total energy supply. The government has targeted to increase Natural gas supply to 15% by 2030. the questions that one would raise are how India can reach this target and that is it worth doing so.

Natural gas has some clear advantages. it is cleaner than coal in terms of both local as well as GHG emissions. it is also far more convenient to use than coal. It requires much less handling than cold and can be easily transported through pipelines. On the other hand, its price on the international market is volatile and India depends significantly on imported LNG, liquefied natural gas.

The proportion of imported gas in the local gas supply has been increasing. As seen in Figure 1, India imported around 50% of gas on average over the last 4 years. The price of LNG is quite volatile on the international market. Thus, domestic gas price also varies. Figure 2 shows gas prices in India, set by the Government, over the years. The price

Figure 1

Domestic Production and LNG Import in Gas Supply

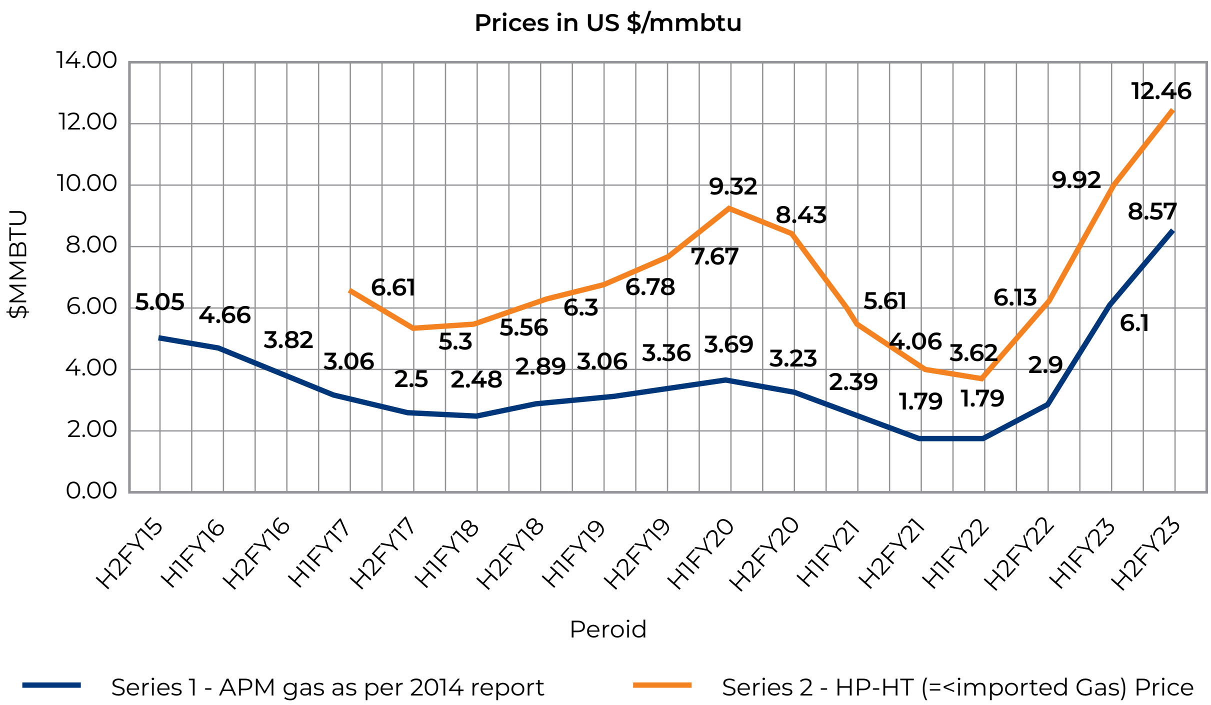


Data from PPAC

of gas from the High-pressure high-temperature (HP-HT) fields is a price set by the GOI as the upper bound on HT-HP gas. The price is set based on the cheapest

Figure 2

Notified Ceiling Prices of APM and HP- HT Gases in India



import price of the competing fuels namely diesel, fuel oil, and LNG. Thus, the actual import cost of LNG could have been higher than shown in Figure 2.

To increase gas supply to 15% of the total energy supply by 2030, India needs to substantially step-up domestic production or else import even more LNG.

The domestic gas production decreased from 2011-12 to 2015-16 and has remained more or less at the same level, as seen in Figure 1. The gas pricing policy still recent years has not attracted many firms to invest in exploration and production (E & P). Till the recent changes in gas prices following the Parikh Committee Report (Parikh Kirit et al, 2022), India had some 14 different prices depending on how the fields were allotted and under what terms. Of these only 7 types of fields produced gas in 2021-22. Table 1 shows the gas produced by these fields and the pricing regime for their output.

Table 1

Gas Production in MMSCM by Different Types of Fields in 2021-22

S. No.	Allotment Basis	Price Regime	Production	Share %
1	Nominated. ONGC +OIL	As per 2014 report	23,500	69%
2-4	Pre-NELP		2453+195+383=3031	9%
5	Coal Bed Methane	Marketing and pricing freedom	682	2%
6	Deep Water (DW), Ultra Deep Water (UDW) and (HP-HT)	Pricing freedom But Under ceiling	6566	19%
7	Miscellaneous		223	1%
	Total		**34000**	**100%**

NELP - New Exploration Licensing Policy

The gas produced by the fields allotted on nomination basis without competitive bidding to ONGC and OIL, contributes the bulk of domestic gas production and is called APM (Administered Price Mechanism) gas. Of the total 34000 MMSCM gas produced in the country in 2021-22, 69% of the gas was APM gas produced by these two public sector firms.

Price of APM Gas

The price of their gas is administered by the government and is called the APM (administered price mechanism) gas price. Since 2014 the price of APM gas has been determined as the weighted average producer price over a year three months ago of four foreign markets, one in the USA, one in Canada, one in Europe, and one in the former Soviet Union, excluding Russia. The price was revised every six months.

In a competitive market, it is the consumer price that should be equalised to the cost of imported gas. Linking the producer price in India to that of foreign producers can create problems. The cost of production varies from field to field, and the formula produced an APM gas price of $1.79 per MMBTU for the period 1-10-2020 to 1-10-2021 did not cover even the marginal cost of production of ONGC and OIL. A $4 per MMBTU would cover their cost and provide a reasonable profit margin. Thus, the Parikh Committee on gas pricing recommended a floor price of $4 per MMBTU for APM gas.

There are many different users of gas with options for using alternative fuels. For example, piped natural gas (PNG) is used by households for cooking. They can also use liquefied petroleum gas (LPG) instead. Both are cleaner and more convenient fuels compared to coal or fuelwood. The latter two create a lot of indoor air pollution and damage the health of people, particularly women and children. The government does promote the use of cleaner fuels. India is also importing LPG for household cooking. However, it is preferred that consumers in urban areas use PNG so that LPG can be distributed to rural households.

So that the PNG users continue to use it and not switch to LPG, the price of PNG has to be a bit lower than that of LPG. Similarly, another user of gas is transport vehicles that use compressed natural gas, CNG. Here again, these vehicles can use diesel instead of CNG. However, for containing urban air pollution, CNG vehicles are preferred.

Based on these considerations a ceiling price of APM gas was fixed at US$ 6.5/MMBTU. The average price of import of crude oil over 20 years in India was US$ 65/barrel. The Gas price corresponding to this is US$ 6.5/MMBTU.

The price of gas has to be determined by a competitive market. However international gas and oil markets are not fully competitive and are affected by geopolitical considerations. Thus, intervention by the government is required, which, however, should be minimal.

The price of gas is related to the price of crude oil. For prices of different energy sources to remain competitive, the Parikh committee suggested that the APM gas price should be based on the import price of crude oil in the previous month and should be revised every month. This price is also for APM gas subject to the floor and ceiling prices.

Price of gas from HP-HT, DW and UDW fields

19% of gas was produced by HP-HT, DW & UDW fields and they had pricing freedom within a ceiling price prescribed by the government every six months. 2% of the gas was by coal bed methane and it had full pricing and marketing freedom.

To provide the gas producers incentive to produce more gas, gas prices for all producers should be liberalized including that of APM gas. If certain consumers are to be subsidized it is best to do that through direct benefit transfer (DBT) to their bank accounts. For the APM gas, the Parikh committee had recommended increasing the ceiling price by US$ 0.50 every year eventually removing all price control.

A market-determined price will help optimize domestic production and consumption.

Would this however lead us to a 15% share of gas by 2030? This, when the country aims to reach net zero GHG emissions by 2070 and gas does emit CO2. Is it even desirable to aim for a 15% share?

Raising Gas Share in the Climate-Constrained World

To explore the potential for gas a projection was made for India. As incomes increase more gas will be used for domestic cooking. Compressed natural gas would be used by the transport sector and we assume that 10 % of vehicles will use CNG by 2050. Since fossil fuel use must be brought down, some 45 % of the vehicles are assumed to be electric. In addition, since India has to expand renewable power, gas-based generation can be used to balance renewable power, which is not available all the time. All these have to be considered in making scenarios for the future. At the same time, the scenario has to be within India's commitments for climate change.

The Paris Agreement set a goal to keep global warming to within 1.50 C. To work out India's obligation for this target, we considered a fair share of the remaining carbon space in the global atmosphere based on equal per capita share for all persons in the world. The IPCC scenarios suggest a range of emissions between 2012 and 2050 that can keep warming within 1.50 C. Based on the lower limit India's share would be 133 GT cumulated emissions over 2012 to 2050. If we consider the median value of the range, it would be 166 GT of CO2 emissions.

We use a multi-sectoral inter-temporal optimizing model with 25 sectors and some 42 activities to produce the 25 goods and services (Parikh K, Parikh J and Ghosh P, 2018). The model solution maximises the present discounted sum of private consumption over the period. The model has 20 different consuming classes, 10 rural and 10 urban, whose demand systems are econometrically estimated. The available total national income is distributed to these classes using log-normal distribution functions. The demand and supply of each sector is balanced every year as also the balance of payment constraint. Production of each activity in each year is within its production capacity, which can be increased by investment in the preceding period.

The Scenarios

We generate three scenarios.

DAU: Dynamics as Usual - These captures current policies.

AMBA: Ambitious Actions - This includes policies under consideration and modest technical progress.

TC1.5: Technical Change and Policies to Stay within 1.50 C Emissions Limit - This shows higher energy efficiency and technical change.

The specification of TC1.5 involves many assumptions.

Since global technology is changing rapidly, we have also assumed a fall in cost of renewable power plants and batteries. Compared to projections made by some international studies we have taken conservative reductions in these costs. Thus, the installed cost of Solar Photo-Voltaic (PV) plants is assumed to fall by 50% compared to that of 2015. The cost of battery storage will fall by 75% over the same period to US$ 50 / kWh by 2050. Since renewable electricity from solar or wind is not available around the clock, they have to be balanced and here natural gas can play an important role.

The efficiency of electricity use will also increase. Electricity consumption in households in 2012 (NITI Aayog, 2015) was for 22% ACs, 21 % lighting, 17 % ceiling fans, 16 % water heating, 12 % refrigerator, and 12 % TV. The use of LED bulbs reduces electricity required by 60% to 80% compared to incandescent bulbs. Energy-efficient appliances are now widely available and bought by consumers. Parikh and Parikh (2018) have shown that the electricity needed for household appliances can come down by 50% or more. Thus, it is assumed that household demand for electricity for each consumer class will fall by 2% per year from 2010.

The use of piped natural gas for cooking in households will cover 90% of the urban population by 2030, which is expected to be 600 million. At around 12 standard cubic meters of gas per month per household with a size of 5 persons, this will require 0.9*600*144/5 million cubic meters per year, which is around 12 million tonnes of natural gas per year or around 13 BCM.

The expert group report for "Low carbon strategy for Inclusive growth" (LCSIG) (Planning Commission, 2014) observed that energy savings from commercial buildings by 2030 could be as much as 10 % over 2010 just from better design and management of buildings, not counting what can be gained from efficient appliances and lighting. When the gains from improved efficiency of appliances are accounted for, new commercial buildings can have electricity requirement that is 50 % lower. However, this may increase investment costs by 10%. We introduced a new technical option for commercial buildings. The level of the selection of this option will be determined by the model solution.

India is pushing electric mobility and the government's target is to have all vehicles sold in 2030 to be electric. There are, however, vehicles that might prefer to use CNG at least for the next two decades or so till the battery costs and weights come down. We have assumed that by 2030, 10 to 15 million cars and 30 to 50 million two-wheelers will run on electricity and some 25 million 4W equivalents (a bus or a truck can be considered as equivalent to five 4Ws) will run on compressed natural gas. This will consume in 2030 around 11 BCM of gas.

The Scenario Results

Are the emissions in the scenario TC1.5 remain within India's share of global carbon space? Table 2 shows the emissions in the different scenarios.

Table 2

Cumulative emissions

Cumulative Emissions	GT CO2		
	DAU	AMBA	TC15
2012-2030	50	44	31
2012-2040	121	99	65
2012-2050	242	178	119

It is seen that in TC1.5 the cumulative emissions from 2012 to 2050 are less than the lower limit of 133 GT of India's share of carbon space. Thus, the scenario is consistent with India's commitments. We now look at natural gas use in these scenarios. The generation of electricity from different sources is shown in Table 3.

Table 3

Total Generation and Shares of Different Types of Plants

	2010	2030			2050		
	DAU	DAU	AMBA	TC1.5	DAU	AMBA	TC1.5
Coal sub & supercritical	67	80	61	28	80	41	17
Natural Gas	12	5	7	9	7	3	12
Nuclear	3	1	10	39	0	6	19
Hydro	13	5	6	6	2	7	6
Solar with and w/o storage	0	1	8	7	2	33	34
Wind with and w/o storage	3	5	8	9	8	10	12
Total (bkWh)	982	3172	3011	3074	10608	8421	8656

Table 3 shows that despite assuming a large share of nuclear power, generation by natural gas is substantial in the TC1.5 scenario. In 2030 a 9% share of 3074 bkWh is 376 bkWh generated using natural gas. The model scenario balances power supply and demand on an annual basis. The gas plants are largely combined cycle ones and so the gas consumption per unit generated is less. 31 BCM of gas is required to generate 376 bkWh.

The sector-wise consumption of natural gas is shown in table 4.

Table 4

Natural Gas Flow across Selected Sectors in BCM

2030	Production	Import	Road Transport	Fertilizer	Power	Household	Government
TC1.5	123	94	11	18	31	13	9

The share of natural gas in total energy consumption is shown in table 5.

Table 5

TC1.5 Total Energy Supply in 2030 MTOE

Coal	Crude oil	Natural Gas	Hydro	Wind	Nuclear	Solar	Wood	Other Renew.	Total	Share of Gas
346	322	195	15	25	314	19	3	47	1287	0.15

It is seen that in MTOE terms natural gas is 15% of total energy in 2030. Thus, the target of 15% by 2030 is met while the CO2 emissions are kept within India's share of global space for a 1.50 C world.

This affects the macroeconomic outcome. The GDP and private consumption are affected. Table 6 shows the GDP and per capita consumption in 2030 and 2050.

Table 6

Macroeconomic Impact in 2007-08 Prices

	DAU	AMBA	TC1.5
GDP in Billion Rs.			
2030	231677	227941	228725
2050	946257	905904	910898
Consumption per capita Rs/year			
2030	60075	62410	63656
2050	326648	328213	329684

It can be seen that compared to the DAU scenario in TC1.5, GDP will go down by 1.2% in 2030 and by 3.7% in 2050. However, consumption goes up by 6% in 2030 and by 1% in 2050. The various efficiency gains and technical progress reduce the need for investment which lowers GDP but, at the same time, increases human well-being.

Concluding comment

To reach the 15% target of natural gas share in total energy, domestic production has to increase to more than 120 BCM from around 35 BCM in 2023, and the share of import will remain at around 45% in 2030, increasing to 95 BCM from around 30 BCM in 2023. At the same time, pushing gas use in households, road transport, power sector, and fertilizer to provide the needed market. If energy efficiency and technical progress assumed in the TC1.5 scenario materialize, and our assumptions in these are conservative compared to many international projections, then we can live within a 1.50 C limit without strain on human well-being.

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10

India has the potential to triple its own biofuel use and accelerate global deployment

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India has quickly joined the ranks of major biofuel producer and consumer thanks to a set of coordinated policies, high-level political support, and an abundance of feedstocks. Over the next five years it has the potential to nearly triple consumption and production by removing roadblocks to higher ethanol blends and diversifying biofuel use to replace diesel and jet fuel. However, it will need to keep an eye on costs, feedstock sustainability and deploy supportive policies to other biofuels beyond ethanol.

India has another opportunity to boost global biofuel deployment as well through the Global Biofuels Alliance, which it launched in 2023 with leaders from eight other countries. Last year the IEA released "Biofuel Policy in Brazil, India and the United States: Insights

for the Global Biofuel Alliance" to support the GBA's development. In it the IEA recommends the GBA focus on developing new and existing markets since over 80% of production is concentrated in four regions: the United States, Brazil, Europe and Indonesia, which account for only half of global transport fuel demand. We also recommend accelerating technology deployment and commercialisation, and seeking consensus on performance-based sustainability assessments.

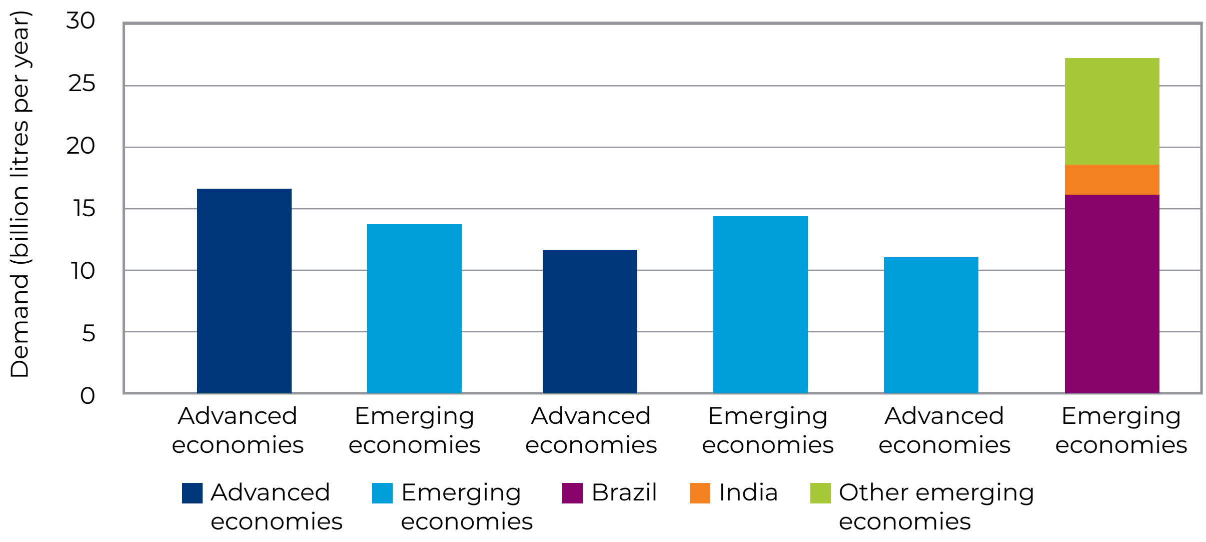
In this brief commentary we consider the global status of biofuels, India's domestic potential and what the GBA can do to help accelerate sustainable biofuels use globally.

Biofuel use is accelerating, led by emerging economies

Over the next five years biofuel demand is set to expand 38 billion litres, a near 30% increase from the last five-year period. In fact, total biofuel demand rises 23% to 200 billion litres by 2028, with renewable diesel and biojet accounting for almost half of this growth with the remainder coming from ethanol and biodiesel.

Figure 1

Five-year biofuel demand growth, main case, 2011-2028



Source: Renewables 2023

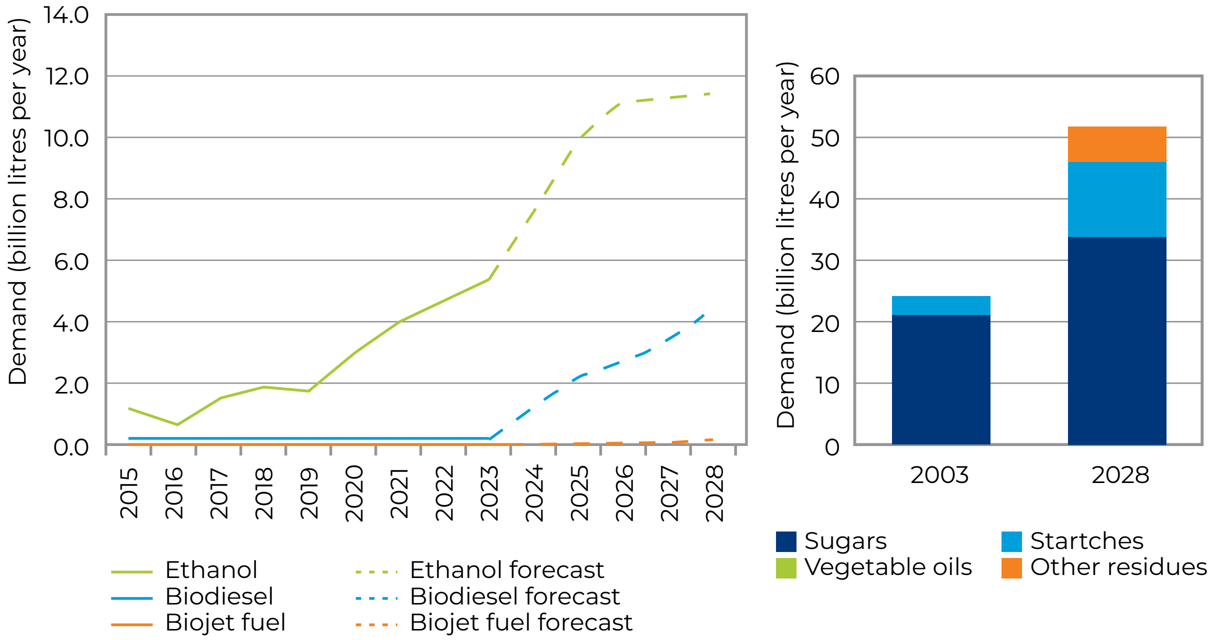
Most new biofuel demand comes from emerging economies, especially Brazil, Indonesia and India. All three countries have robust biofuel policies, rising transport fuel demand and abundant feedstock potential. Ethanol and biodiesel use expand the most in these regions. Although advanced economies including the European Union, the United States, Canada and Japan are also strengthening their transport policies, biofuels growth is constrained by factors such as rising electric vehicle adoption, vehicle efficiency improvements, technical limitations and high blending costs in some markets. Renewable diesel and biojet fuel are the primary growth segments in these regions.

India is the third largest global ethanol producer and can build on its rapid growth

India is now the world's third largest producer and consumer of ethanol thanks to nearly tripling production over the past five years. It has potential to expand further with the right policies, keeping costs in check and securing sustainable feedstocks. In 2018 India released its National Policy on Biofuels which set blending targets for ethanol (20% blending by 2030) and biodiesel (5% by 2030), feedstock requirements for different fuels and laid out the responsibilities of 11 ministries to coordinate government actions. Beyond blending targets, India established guaranteed pricing, long-term ethanol contracts, and technical standards and codes. Financial support for building new facilities and upgrading existing ones was also provided. Buoyed by its success, the Government moved the 20% volume blending target for ethanol forward by 5 years to 2025-26, which was enshrined in an updated National Policy on Biofuels in 2022.

Figure 2

Biofuel consumption in the accelerated case (left) and feedstock demand (right) in India, 2015 to 2028



Note: Biofuels consumption is from Renewables 2023, assuming India achieves 20% ethanol blending by 2025/26, is on track for 5% biodiesel blending by 2030 and achieves 2% biojet blending for international flights by 2028

Supported by these policies, ethanol for blending in gasoline production and demand nearly tripled between 2018 and 2023 and now stands at near 12% (7% on an energy basis). Sugar cane provides most ethanol production with the remainder from food grains such as maize and surplus rice stocks determined by the Food Corporation of India. To diversify feedstocks beyond sugar cane, India provides separate pricing for maize-based ethanol and includes ethanol produced from agricultural residues such as cotton stalks, wheat straw, rice straw, bagasse and bamboo.

Achieving 20% ethanol blending on average across India will require increasing the fleet of vehicles capable of accepting higher ethanol blending levels. India is encouraging flex-fuel vehicles and retrofits are possible for older vehicles, including two wheelers. In addition, a greenhouse gas (GHG) measurement and reporting requirement would help India assure and improve GHG reductions from biofuel use in the transport sector. India will also need to continue to diversify feedstocks to help avoid shortages as it experienced at the end of 2023. New cellulosic ethanol plants, one completed last year, and three others under development, will help.

India has other opportunities to expand biodiesel for use in diesel vehicles and biojet fuel as a replacement for jet fuel. The government has already established a 5% biodiesel target by 2030 which would require almost 4.5 billion litres of biodiesel per year according to IEA estimates. Mobilising production will require a similar mix of policies as provided for ethanol including production support, guaranteed pricing and feedstock support, especially for mobilising residue oils like used cooking oil and vegetable oils grown on marginal land.

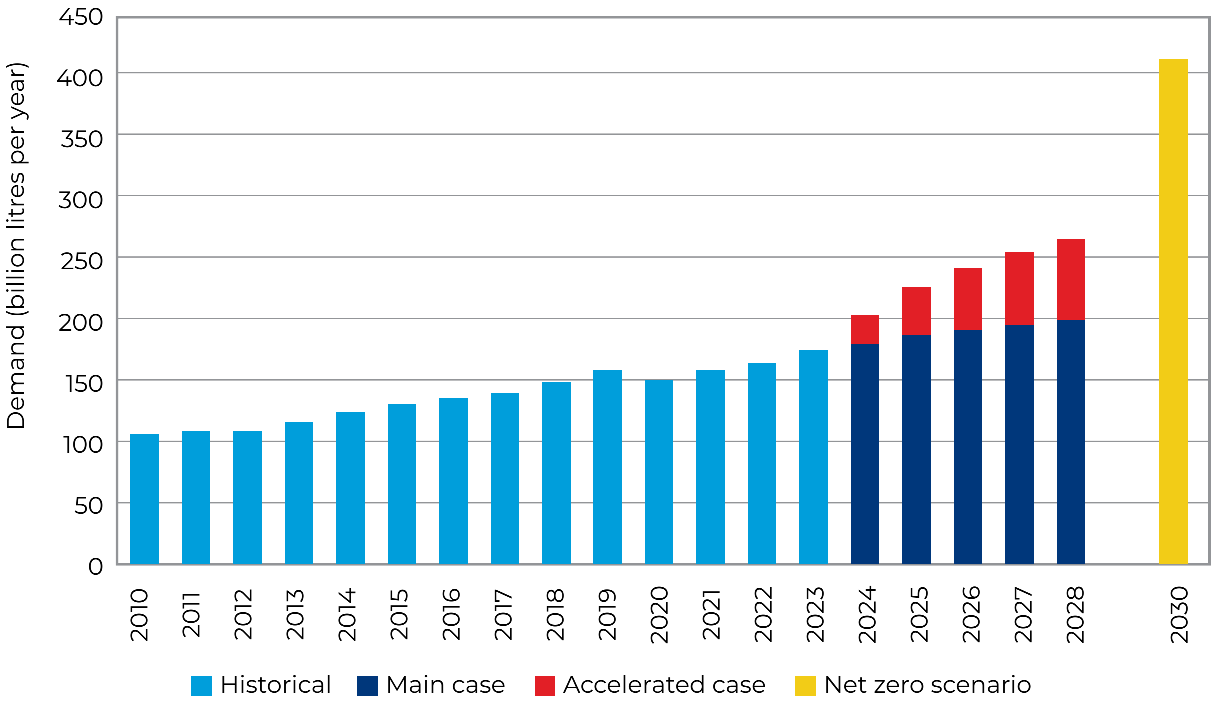
Biojet fuel is another growth area. On 25 November 2023, the Ministry of Oil, Petroleum and Natural Gas announced indicative blending targets of 1% by 2027 and 2% by 2028 for international flights leaving India. We estimate this would require near 100 million litres of biojet fuel per year, likely to come from residue or vegetable oils grown on marginal land. However, future growth could come from other technologies such as alcohol-to-jet using ethanol and gasification technologies whereby agricultural, forestry and municipal solid waste can be converted into jet fuel.

Biofuel demand must nearly triple on a net zero pathway

World leaders left COP28 this year with clear priorities to triple global renewable capacity, double progress on energy efficiency, drive down methane emissions by 2030 and transition away from fossil fuels – four of the five key priority areas for success indicated by the IEA well before the COP28 gathering. Biofuels are one of the keys to transitioning away from fossil fuels as a complementary measure to electric vehicles and vehicle efficiency improvements. They are also compatible with existing vehicles and over the medium-term play a significant role in reducing emissions from long-distance road, air and maritime transport. In the IEA's net zero scenario, biofuels production nearly triples from current levels by 2030, but the world is not on track for this.

Figure 3

Global biofuel demand, main case, accelerated case and net zero scenario, 2010 – 2030



IEA. CC by 4.0.

Source: Renewables 2023 and the World Energy Outlook 2023

In the IEA's accelerated case strengthening existing policies, establishing new targets and raising biojet fuel doubles annual historical growth rates to 8% through 2028. Nearly half of this additional growth, 29 billion litres of new demand, results from strengthened policies in existing markets such as the United States, Europe and India (for ethanol), and an additional 21 billion litres comes from new markets (biodiesel in India and ethanol in Indonesia). Biojet fuel offers a third growth avenue, expanding to cover nearly 3.5% of global aviation fuels – up from 1% in the main case.

However, even this level of growth falls short of a net zero scenario. To align with a net zero pathway, biofuels production from new processing technologies to access a large agricultural and forestry residue base must also quintuple by 2030, necessitating significant developmental support, as most remain pre-commercial. To address GHG emissions intensity, technologies such as CCUS applied to biofuel projects can very effectively reduce GHG emissions, with lower feedstock demand.

Finally, biofuel production must expand significantly outside of the United States, Brazil, Europe and Indonesia that dominate production and use today. In all cases, predictable long-term policies with clear sustainability requirements are crucial to minimise uncertainty and stimulate investment.

The Global Biofuels Alliance can help expand sustainable biofuels

On the 9th of September 2023, India launched the Global Biofuels Alliance with the leaders of Singapore, Bangladesh, Italy, the United States, Brazil, Argentina, Mauritius and the UAE on the sidelines of the G20 summit. As of January 2024, the GBA now has 22 member countries alongside 12 international organizations. The GBA aims to accelerate the deployment of sustainable biofuels. The Alliance is a welcome addition to international and domestic efforts to expand sustainable biofuel supplies in line with a net zero trajectory. Despite the urgent need to increase the production of sustainable biofuels to cut transport emissions and ensure energy security, current growth is lagging what is required to achieve global net zero emissions by mid-century, according to the IEA's NZE Scenario. However, with the right policies and practices, rapid sustainable biofuel deployment is achievable. The GBA can help get sustainable biofuels on track by focusing on three main areas:

Identify and help develop markets with high potential for biofuels production:

Over 80% of sustainable biofuels production and use is in the United States, Brazil, Europe and Indonesia. However, total transport fuel demand from these countries accounts for less than half of global transport fuel demand. Expanding sustainable biofuels use will therefore require expansion into new markets and expanded production in existing markets. Augmenting sustainable supplies in each market requires enhancing measurement and monitoring for sustainable supplies, assessing mixed technology deployment pathways and developing regional-specific policy packages, while learning from existing experiences.

Accelerate technology deployment to commercialise advanced biofuels:

Advanced biofuels must grow 11 times by 2030 from 2022 levels in the IEA's NZE Scenario, doubling total biofuels production over the same period. However, planned investments to date remain well below this level of growth.

Seek consensus on performance-based sustainability assessments and frameworks:

More consistent and internationally recognised sustainability frameworks would help improve measurement and reporting, improve GHG reductions, encourage sustainable biofuels trade and help new markets incorporate lifecycle GHG accounting into their biofuel policies.

India has already demonstrated how to quickly accelerate biofuel use. It now has an opportunity to extend those lessons learned to other biofuel types. Its leadership with the Global Biofuels Alliance is a welcome addition to international efforts to accelerate sustainable biofuels demand.

11

Past, present & future of Compressed Biogas as an alternative energy

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The inception of biogas in India traces back to 1859 when the world witnessed the construction of its first biogas plant in a leper colony in Mumbai (Bombay). Over the years, biogas production in India has primarily relied on dairy manure as a feedstock, with "gobar" gas plants becoming integral to rural areas, particularly in villages. In recent decades, research organizations focusing on rural energy security have revolutionized biogas systems, leading to the development of more efficient and cost-effective designs, such as the renowned Deenabandhu model.

The biogas produced from small-scale digestion facilities through anaerobic digestion of manure is commonly referred to as "gobar gas." It is estimated that over 2 million households in India, utilize such facilities due to the prevalence of livestock. These digesters, often airtight circular pits made of brick or concrete with pipe connections, receive manure directly from cattle sheds. Water is added to the pit, and the resulting biogas is channelled to kitchen fireplaces through control valves. Notably, the combustion of biogas produced in this manner is characterized by minimal odor and smoke, making it one of the most environmentally friendly energy sources for rural needs. One noteworthy system following this design is the Plastic Digester. Some variations incorporate vermiculture to further enhance the slurry produced by the biogas plant for use as compost.

The Deenabandhu Model, gained popularity in India, typically boasts a capacity of 2 to 3 cubic meters and can be constructed using bricks or a ferrocement mixture.

Recognizing the significance of utilizing Municipal and agro waste and biomass in rural areas, the Union government of India has implemented various schemes aimed at uplifting the rural economy and job potential. Large-scale anaerobic digesters in India, presenting a viable alternative to fossil fuels.

India's need for CBG-Compressed Bio gas

The surge in international petroleum prices, driven by a resurgence in demand, has led to a notable impact on retail petrol prices in various parts of the country, surpassing all previous highs. As the world's third-largest crude oil importer, India heavily relies on fossil fuels to meet its energy demands. However, this extensive dependence not only strains India's fiscal budget but also raises concerns about its growing accountability in the face of climate change.

Recognizing the need for a shift, India is adapting to changing times and aiming to reduce its oil import bills. The strategy involves a significant focus on alternative fuels to diversify its energy sources. The Indian government is resolute in restructuring its energy mix, with a specific goal of increasing the natural gas component from the current 6.5% to 15% by 2030.

Evident progress in this direction is marked by the launch of initiatives like the Sustainable Alternative Towards Affordable Transportation (SATAT). This ambitious scheme aims to establish 5,000 Compressed Bio-Gas (CBG) units nationwide, with a target to produce 15 million tons of CBG by 2023. This endeavour could attract investments worth Rs 2 trillion.

The widespread production and utilization of CBG hold multifaceted benefits for India. Beyond reducing the nation's reliance on crude oil imports, it has the potential to bolster farmers' income and rural employment. Furthermore, the solid by-products of CBG can serve as bio-manure, enhancing agricultural output. Thus, the entire CBG value chain not only offers economic advantages but also contributes positively to environmental sustainability. These opportunities are waiting to be harnessed by entrepreneurs and society at large.

Present status of Biogas in India

Under the Sustainable Alternative Towards Affordable Transportation (SATAT) scheme, Oil and gas Marketing Companies (OMGCs) play a crucial role by inviting expressions of interest from potential entrepreneurs for the establishment of Compressed Bio-Gas (CBG) plants. These plants are intended to supply CBG to OMGCs for use as automotive, domestic and industrial fuel. The CBG Plant Owner assumes responsibility for the comprehensive project lifecycle, encompassing planning, preparation, engineering, execution, storage of raw material, operation and maintenance of the plant, and the upkeep of the final product.

The City Gas Distribution sector is poised for significant expansion, with coverage expected to double every 2 years. Key factors facilitating the success of the SATAT scheme include the offtake and marketing of CBG by OMGCs, assured long-term pricing, priority sector lending, central financial assistance provided by the Ministry of New and Renewable Energy (MNRE), nominal bank guarantees, fortnightly invoice clearance, and the freedom for Plant Owners to sell excess CBG to consumers other than OGMCs.

The government is actively working towards the synchronization of CBG with City Gas Distribution pipelines, ensuring a seamless process for the evaluation, sale, and distribution of CBG. In addition to these scheme enablers, entrepreneurs stand to benefit from incentives offered by both state and central governments. These incentives may include investment subsidies, interest subsidies, and exemptions from stamp and electricity duties. This comprehensive support framework aims to encourage the widespread adoption of CBG, contributing to the growth of the alternative fuel sector in India.

Future of Biogas in India

The energy landscape is completing a full cycle. Historically, wood and agriculture served as the primary sources of energy until petroleum emerged and revolutionized traditional modes of operation. In the early 20th century, biomass was prominence as a vital energy source, not only providing fuel but also fulfilling essential daily needs such as food, fodder, fertilizers, and fibres. However, the reliance on fossil fuels, despite its advantages, brought about several disadvantages, prompting a renewed recognition of biomass as a crucial raw material for both material and energy production.

Microbial energy conversion processes, particularly biogas production, are proving to be highly advantageous in this evolving energy scenario. These processes generate by-products that can be efficiently recycled as fertilizer and soil conditioner, contributing to a sustainable and circular approach.

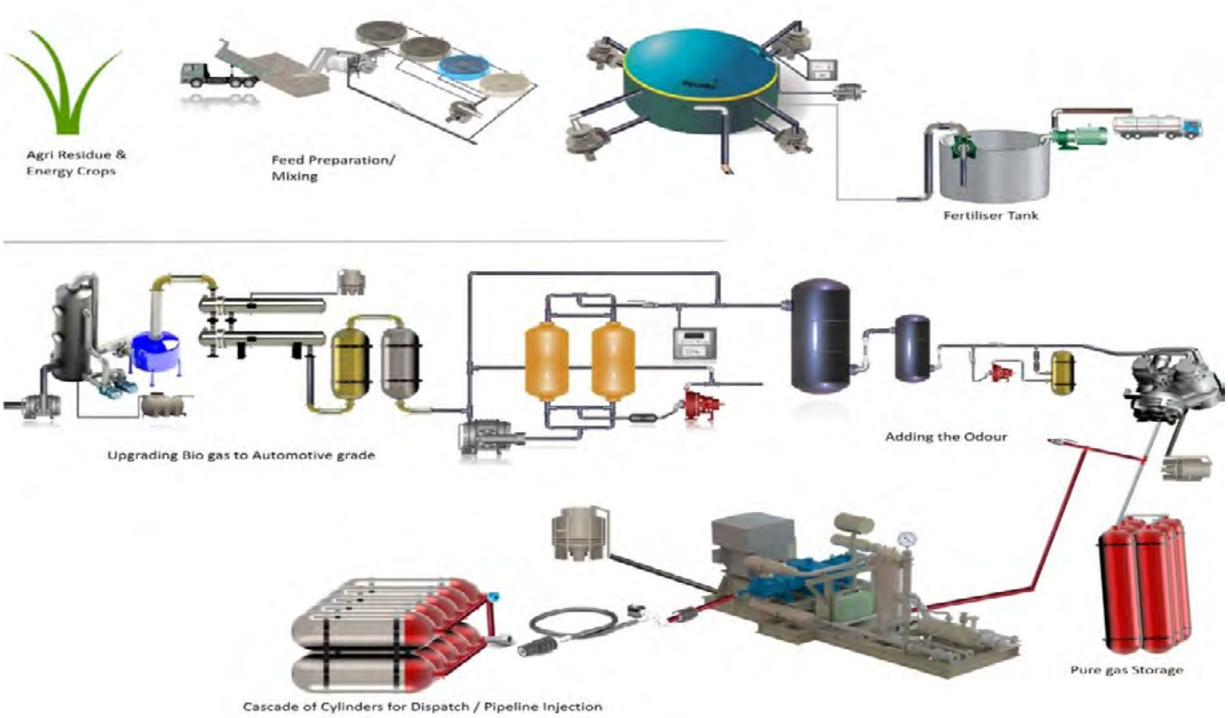
With global land availability is finite and only a fraction is suitable for agriculture. As the global population continues to grow, there is an increasing demand for both food and energy. Agricultural biomass and energy derived from municipal organic waste are playing a pivotal role in addressing this challenge, offering a conclusive solution to waste management. This approach not only helps in environmental conservation but also enables the farming community to directly benefit from the expanding industrial sector by becoming energy suppliers.

Biogas production stands out by Plant residues and energy crops plants that do not compete with food production. Agri residues gets used in Biogas production instead of burning or degrading in the air. Energy crops such as Napier grass can grow even in soils unsuitable for traditional agriculture. Various energy-rich substrates, including Napier Grass, Maize, Paddy straw, Miscanthus, water hyacinth, and more, are being employed in the process. Additionally, an abundance of organic industrial and agricultural by-products, residues, and bio-wastes can serve as valuable substrates for anaerobic digestion, contributing to the development of sustainable and diversified energy sources. This holistic approach marks a significant step towards a more balanced and eco-friendly energy future.

With gaseous fuels growing and Biogas blending being mandated, we can expect a greener and better future.

Figure 1

Process Flow Diagram - Compressed Bio Gas Plant



12

Impact of Biodiesel Blending on Indian Oil Market by 2030

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Introduction

Rising overall population, urbanization, rapid industrialization, and economic growth have led to a significant rise in fossil fuel consumption to meet the ever-growing energy demand. Energy has become a critical resource, supporting various routine activities in transportation, industrial, and agricultural sectors. Conventional fuels are preferred owing to their high energy density, combustion efficiency, and ease of transportation and storage.

India is currently experiencing a substantial surge in energy demand for road transport, with projections indicating a two-fold increase by 2040, with diesel-based freight transport driving half of this growth. The overall Indian fleet is also predicted to grow by around 300 million vehicles of various types (IEA, 2021), resulting in a significant amount of impact on the energy demand from country's transport sector. Carbon emissions from the transport sector are also projected to grow by four-fold, reaching 1164 million tonnes by 2050, with the transport sector's share in total emissions rising to 19% (TERI, 2021).

This growing demand for energy and the associated surge in carbon emissions poses serious challenges for India and the world in terms of climate change. It is becoming imperative for policymakers, industries, and individuals to focus on sustainable alternatives, energy efficiency, and clean technologies to mitigate the adverse effects of these trends. Promoting renewable energy sources and encouraging the adoption of alternative fuels and technologies are some potential strategies to reduce the impact of the growing energy demands from the transport sector and reducing oil import burdens.

The transport sector in the country heavily relies on diesel-powered commercial vehicles, including trucks, buses, and other transport/non-transport vehicles. While these vehicles have proven crucial for freight movement and passenger transportation, their exhaust emissions pose severe environmental and health challenges. Diesel commercial vehicles have been major contributors, emitting harmful pollutants such as nitrogen oxides (NOx), particulate matter (PM), and greenhouse gases (GHGs).

In the recent years, India's demand for fuel and petroleum products has increased rapidly, leading to 87.3% reliance on imported crude in 2022-23, up from 85.5% in 2021-22 (PPAC, 2023). This further indicates the need for increased investment in domestic oil production alternatives to enhance energy security and reduce import dependence.

As the nation seeks to transition towards a greener future, the adoption of biodiesel presents a promising area to reduce emissions and foster sustainable growth in the transport sector. Government's commitment to achieve 5% biodiesel blending (blend of 5% biodiesel with 95% of conventional diesel) in the country's fuel mix by 2030 as outlined in National Policy on Biofuels, 2018 is a crucial step towards reducing transport emissions and enhancing energy security with assisting India's oil import dependence.

Biodiesel- a sustainable & potential alternative source

Biodiesel is one of the alternative fuels and can be produced from renewable sources like edible oils, non-edible sources, waste oils and animal fats.

In India, biodiesel is produced primarily from non-edible oils, animal tallow, and used cooking oil. Biodiesel in its pure form is termed B100 or neat biodiesel and can also be blended with conventional diesel (Konishi, 2010).

There is a need for sustainable and appropriate replacement of fossil fuels to reduce import duty on oil and lower exhaust emissions. In addition to being renewable, non-toxic, and eco-friendly, biodiesel is an ideal alternative to diesel engines (Jamal, 2023). Various other potentials related to biodiesel are:

- it can reduce our dependence on oil imports.
- it can support reducing GHG emissions.
- it can support boosting our domestic economy.

Biodiesel significantly reduces the tailpipe emissions of carbon monoxide, unburned hydrocarbons, and other particulate matter compared to conventional diesel and supports the environment. A major component of acid rain is sulphur dioxide, and sulfates are virtually eliminated with biodiesel.

Nitrogen oxide emissions are either reduced or increased depending on the engine duty cycle and testing methods. The overall ozone-forming potential of emissions from biodiesel is less than half of that measured for the diesel counterpart (Jamal, 2023).

Table 1

Biodiesel emissions compared to conventional diesel

Emission Type	B5	B7	B10	B20	B50	B100
Particulate Matter	-3%	-4%	-6%	-12%	-27%	-47%
Hydrocarbons	-5%	-8%	-11%	-20%	-43%	-67%
Carbon Monoxide	-3%	-4%	-6%	-12%	-28%	-48%
SOx	-5%	-7%	-10%	-20%	-50%	-100%
CO_2	-4%	-5%	-8%	-15%	-38%	-76%

**Note on emission reductions: The above analysis is based on research and studies conducted by the University of Idaho and the USDA, including the complete direct and indirect GHG emissions of biodiesel production. This latest study is a further update to the previous methods used by USEPA in 2010. Global warming potentials of various greenhouse gases are weighted to present results in CO2 equivalents.*

Source: Biodiesel Manufacturers Association of India (BMAI)

International experiences

As a strategic approach to address energy security, reducing imports and environmental benefits, countries all over the world are setting mandates for biodiesel blending. Countries like Indonesia, Malaysia, Colombia, Philippines have embraced crude palm oil as a predominant raw material for biodiesel production, achieving blending rates of 28.6%, 10%, 11%, and 3% respectively as of 2021. In contrast, several other countries like Brazil (with a 2021 blending rate of 11%), the United States, the European Union, Argentina, Thailand, Canada, have chosen a more varied array of feedstocks for their biodiesel manufacturing, encompassing resources such as animal tallow, soybean oil, rapeseed oil, sunflower oil, and used cooking oil for biodiesel production.

A noteworthy advantage is that the production resources are abundantly available within the majority of these countries, rendering them extremely feasible for efficient biodiesel production.

India's push towards biodiesel blending.

Policy initiatives by India, such as the Biodiesel Purchase Policy (2006), direct sales by manufacturers (2015), and increased blending limits (2017), have significantly promoted biodiesel adoption in the country. The National Policy on Biofuel (2018) targets 5% blending by 2030, while efforts to utilize used cooking oil (UCO) for biodiesel production have also been outlined. These measures demonstrate India's commitment to reducing oil imports and curbing emissions from diesel commercial vehicles, fostering a greener and sustainable transport sector.

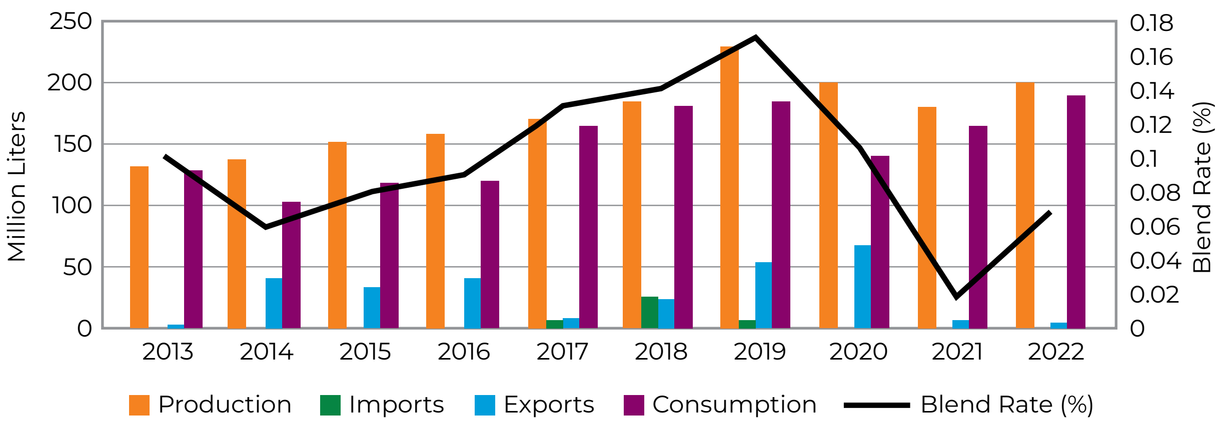
Biodiesel Market in India

India's biodiesel market has remained largely informal and dispersed, with limited domestic production. Additional factors consist of energy prices, the Russian-Ukraine conflict, and surge in feedstock prices observed globally due to various supply restraints, etc. The COVID-19 pandemic and high operational costs have stressed the Indian biodiesel industry in the last few years (USDA, 2022).

The demand continues to be inadequate as the majority of biodiesel produced goes to informal sectors. India's biodiesel market has substantial unused capacity, primarily due to a lack of suitable feedstock sources and government support mechanisms to stimulate demand (Jamal, 2023). Figure 1 depicts biodiesel production, consumption, import-export with blend rate trend in the country over the past years.

Figure 1

Biodiesel trend in India



	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Production	132	138	152	158	170	185	230	200	180	200
Import	0.3	1.7	0.8	2.7	7.1	25.2	7	1	1	1
Export	3.9	41.5	33.1	41.7	7.6	23.1	54	68	6	4
Consumption	128	102	118	119	165	180	185	140	165	190
Blend Rate (%)	0.1	0.06	0.08	0.09	0.13	0.14	0.17	0.11	0.02	0.07

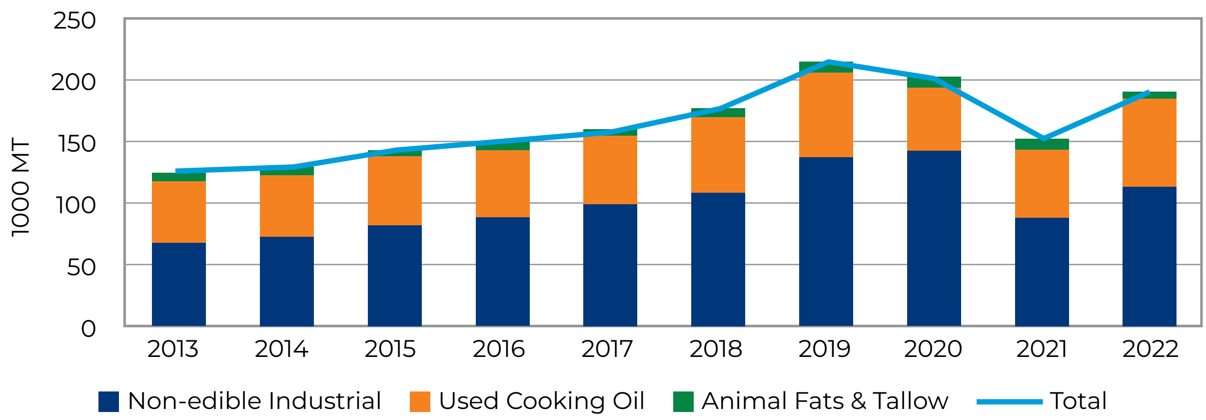
Source: (USDA, 2023)

The long-standing concern in field trials is the use of tree-borne oilseeds and non-edible oilseeds as feedstock, given their low yields on non-arable, rain-fed lands. Despite a surge in production due to policy initiatives, maintaining consistency remains a challenge. The current (in 2022) blend rate is 0.07%, witnessing a significant increase from 0.02% in 2021 (USDA, 2023). This blend rate is directly influenced by production levels, which were notably affected by the COVID-19 pandemic.

Figure 2 depicts the biodiesel production trend in India from various feedstock sources. Non-edible sources account for the majority of biodiesel production, while the utilization of edible oil is restricted due to food security considerations. Additionally, the use of animal tallow is limited as it fetches a better price from export. However, the potential of used cooking oil as a biodiesel source has been significant, especially following the launch of the RUCO initiative by the Food Safety and Standards Authority of India (FSSAI) in 2018.

Figure 2

Biodiesel production in India from multiple feedstocks



	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Non-edible Industrial	70	75	85	90	100	110	140	145	90	115
Used Cooking Oil	49	50	55	55	55	60	65	50	55	70
Animal Fats & Tallow	7	6	5	6	6	8	10	9	9	6
Total	126	131	145	151	161	178	215	204	154	191

Source: (USDA, 2023)

Impact on the Oil and Gas Market

The achievement of 5% biodiesel blending by 2030 is likely to have several benefits on India's oil and gas market. Primarily, it will lead to a reduction in the country's high dependence on traditional petroleum products. As a result, the demand for crude oil imports may decrease, potentially enhancing India's energy security and reducing its vulnerability to fluctuations in global oil prices. Based on the consumption trends of High-Speed Diesel (HSD) from 2012 to 2022, India has experienced a notable usage surge at a Compound Annual Growth Rate (CAGR) of about 2% taking expected diesel consumption to reach around 95.24 million tonnes by 2030. In Business-as-Usual (BAU) scenarios, achieving 5% biodiesel blending in 2030 could potentially replace about 4.76 million tonnes of HSD that will have a significant impact of about 3% on net imported oil dependence by 2030.

The increased utilization of biodiesel will also offer an opportunity for India to utilize its abundant agricultural resources to produce cleaner and renewable energy. This shift can foster rural development, create new employment opportunities, and strengthen the country's agricultural sector by providing farmers with an additional market for non-edible oilseeds and waste oils.

Conclusion

Achieving 5% biodiesel blending target by 2030 and, country needs to address numerous challenges in terms of quality and type of domestically available feedstock sources like non-edible, waste oils and animal tallow, high feedstock prices, and ensuring a continuous and an integrated supply chain management. Adequate investment in research and development is required to optimize biodiesel production processes and improve its compatibility with existing vehicle technologies (USDA, 2022).

As diesel is one of the most used fuels in the commercial segment, it will have a significant impact on the emission reduction from the transport sector. The transition towards greater biodiesel usage in India's transport sector will not only decrease the country's reliance on traditional petroleum products but also reduce vulnerability to fluctuations in global oil prices. By potentially replacing a significant portion of HSD consumption, India can impact its foreign reserves and imported oil dependence positively.

Policymakers, industries, and other relevant stakeholders must work together to accelerate the production, blending, and adoption of biodiesel. Adopting a step-by-step approach, establishing achievable short-term goals and government's push in terms of introducing National Feedstock Programme and/or Production Linked Incentives schemes to facilitate optimal production, regularization, and feedstock utilization could be one of the potential areas of work which could serve as a solid foundation for reaching the target of B5 by 2030.

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Energy Price Insurance – An Effective and Robust Global Practice

13

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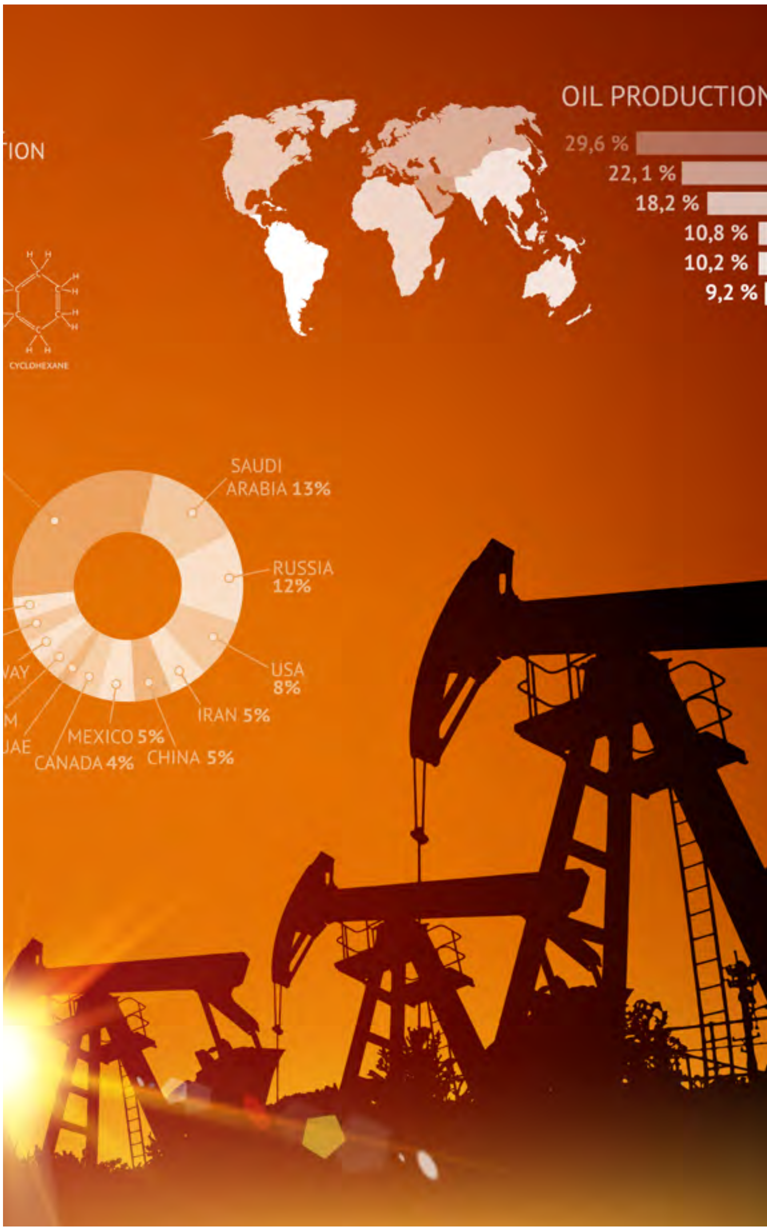
India's G-20 Presidency this year has witnessed landmark and historic slew of socio-economic and geo-political resolutions. 'Energy' was the standout agenda around which dialogue and deliberations evolved and led to fruitful outcomes for all the countries. Abhishek Shastri Abhishek Shastri



Balanced Approach towards a Carbon Neutral Energy Mix

The key words that did the rounds frequently are 'Energy Transition', 'Energy Security', 'Sustainability', 'Reliable', 'Cleaner', 'Accessible', 'Affordable', etc. Hence, definitely what we gather here is that there is a call for cleaner and renewable energy, but this accomplishment must go hand in hand with energy security, accessibility and sustainability. And that is why there is an energy mix that exists today which can only step by step or gradually transit to a more balanced energy mix with renewable energy as a major component.

G20's outcome document lays a groundwork for two promising future fuels i.e. Hydrogen and Bio Fuels. Global Biofuel Alliance by itself is a paradigm shift in sustainable energy and economic strategy. Parallelly at G20, India, US UAE, EU, France, Italy, and Germany also signed MOU to establish India - Middle east - Europe Economic corridor (IMEC), envisioned as a network of transport corridor.

Sustained economic growth for any country, for a large part of it, depends on the continuous availability of the energy resources that firsthand should be economically viable and secondly in line with the sustainable development goals, should also be socially acceptable and environment friendly. Sustainability as a concept is linked generally only to environment. However, when we talk of commodity and energy security, overcoming these insecurities becomes a question of survival first and then sustaining the same. In that breakdown, the concept of 'economic sustainability' focuses on conserving the natural resources that provide physical inputs for economic production, including both renewable and exhaustible inputs.

India - Energy Intensive Economy

India's crude oil consumption stood at 1,869 Million Barrels during FY23 while India's natural gas consumption stood at 2,393 Million MMBtu during FY23.

These numbers are nothing short of indicating how oil and gas are the crucial elements of the Indian economy. Though there are several energy sources both renewable and non-renewable, the world itself continues to be heavily dependent on fossil fuels, predominantly oil, natural gas, and coal because of their cost efficacy, efficiency and availability. Moreover, crude oil is largest consumed energy commodity, that is, about one-third of the total energy consumed in the world. Similar is the situation in India. Commensurate with being the second-largest country in the world in terms of population, India holds the distinction of being the third-largest consumer of oil, next only to China and the US. India is also the third-largest importer of crude oil, importing more than 80% of its oil requirement.

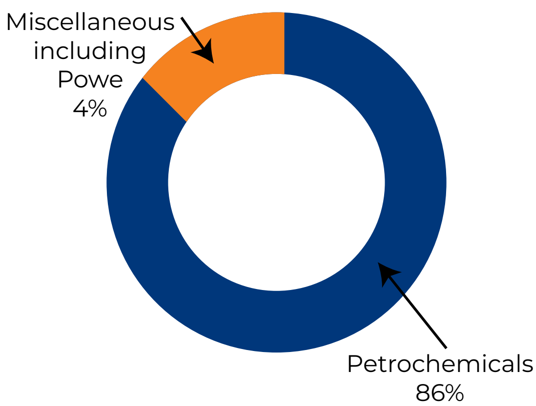
Domestically, oil is the largest source of the country's total energy supply next only to coal and is the largest in terms of total final consumption. The demand for oil is increasing rapidly. Yet, owing to low natural endowment and stagnant domestic production, India's reliance on imports for meeting the demand-supply gap is high. Also, the oil and gas sector are one of the six core industries in India and is among the most traded commodities. It is, therefore, natural that the implications of extreme changes in global prices of crude oil on the Indian macro economy would be profound. Additional concern for Indian economy also lies in the fact that we import more than 80% of our oil requirement. Hence, we are vulnerable to any surge in oil prices, the impact that can affect our import bill, stoke inflation and widen the trade deficit too. In other words, fluctuation in oil prices beyond a threshold (if not hedged) is capable of disrupting the smooth functioning of the nation's economy.

Addressing concerns about energy security, the fact that has been emerging from government and industry discussions is that India will need to pursue an aggressive upstream policy to ensure energy security as the bulk of the demand will come from the oil and gas sector in the foreseeable future, despite the transition to cleaner fuels changing the energy landscape.

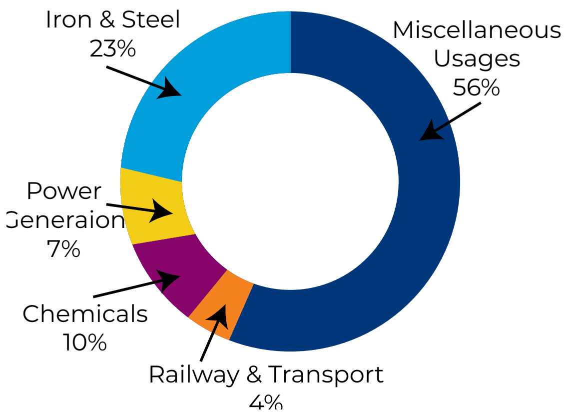
If we look at the exposure of India's industries to crude oil, it's by-products and natural gas (as depicted in below graphs), it clearly suggests that energy security, accessibility and affordability are equally important for an inclusive growth of energy intensive and developing nations like ours.

Figure 1

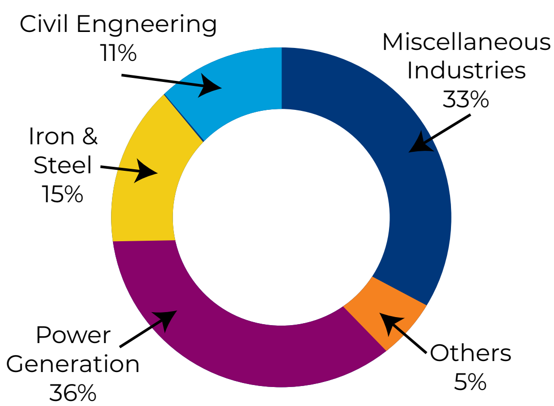
Industry Wise Consumption of Naptha in India during 2022-23



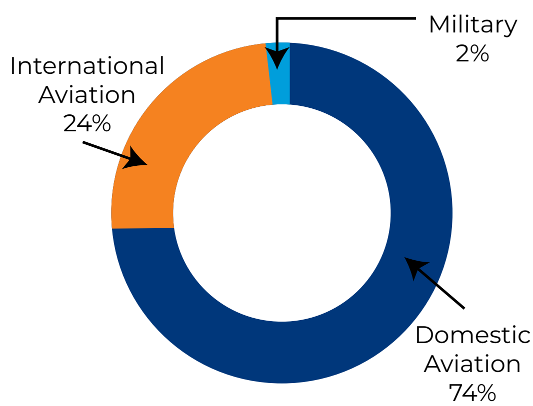
Industry Wise Consumption of Furnace Oil / Low Sulphur Heavy Stock in India during 2022-23



Industry Wise Consumption of Light Diesel Oil in India during 2022-23



Industry Wise Consumption of Aviation Turbine Fuel in India during 2022-23



Energy Security and Accessibility

India, though being predominantly import dependent for its crude oil consumption is striving to ensure energy access through a combination of domestic production and imports.

India produced 6.85 Million metric tonnes (MMT) of crude oil during Q1 FY24, 4.1% lower than the corresponding period of the previous financial year. Crude oil imports for similar period were 60 Million metric tonnes (MMT), 1.1% lower than the corresponding period of the previous financial year.

Natural gas production in India stood at 8,564 MMSCM during Q1 FY24 which was higher by 0.1% compared with the corresponding period of the previous financial year. LNG imports for similar period were 7,748 MMSCM, 4.0 % higher than the corresponding period of the previous financial year.

Further on domestic production front, a recent report released by S&P Global Commodity Insights stated that India's oil and gas production is expected to achieve a mid-decade peak between 2023 and 2032, around 2027, driven by the KG-Basin projects operated by Reliance Industries Limited and Oil and Natural Gas Corporation (ONGC).

Infact according to the International Energy Agency (IEA), primary energy demand is expected to nearly double to 1,123 million tonnes of oil equivalent, as India's gross domestic product (GDP) is expected to increase to US$ 8.6 trillion by 2040.

Crude oil consumption is expected to grow at a CAGR of 5.14% to 500 million tonnes by FY40 from 202.7 million tonnes in FY22. Natural Gas consumption is forecast to increase at a CAGR of 12.2% to 550 MCMPD by 2030 from 174 MCMPD in 2021.

Government of India's four-pronged energy security strategy based on diversifying energy supplies, increasing India's exploration & production footprint, alternate energy sources and energy transition through a gas-based economy, green hydrogen etc. is a step towards ensuring energy security and accessibility.

Affordability / Cost-effective Pricing

As we understand, oil and gas prices also substantially influence the Indian economy. With a larger import and global pricing, most of the factors impacting these prices are uncontrollable. Ranging from OPEC announcements aiming at balancing petroleum policies and overall demand-supply globally, Geo-political events like Russia – Ukraine war disrupting the supply side, political sanctions of some oil producing countries, weather variability and oil & gas demand from leading consuming countries like China – all the factor impact oil prices, sometimes even moving them to uncomfortable zones. However, these are uncontrollable factors. Hence the actionable which is in our hands for sustainability is how best we can optimize consumption and manage our price risks.

Moreover, fuel and energy prices have a cascading effect on prices as they push up costs at every stage of production. Recent unofficial estimates suggest that in an optimistic scenario of international oil prices at $100/barrel, domestic inflation is likely to go up by 52-65 basis points (bps).

Moreover, this increase in oil prices comes in the backdrop of already high inflation rates and the fact that the most obvious impact of high oil and gas prices in India is on domestic inflation. 'Fuel and power' have 13.20 per cent weightage in the Wholesale Price Index (WPI), and 'fuel and light' have 6.8 per cent in the Consumer Price Index (CPI).

Sensitivity for O&G Value Chain

Oil & Gas sector across the value chain is highly sensitive to the energy prices especially being the major fuel feedstock, it directly impacts the cost of operations and in turn the profitability margins of the companies. It really doesn't matter that where does this company stand in the value chain. Today we are not operating in the monopoly or monopolistic environments and there is also a huge reduction in information asymmetries with technological progress. Hence what really worked for some companies in the past in the form of 'pass through mechanism' or 'long-term bilateral agreements' doesn't clearly fit into today's dynamic markets which are continuously evolving. The only rule is adaptation to the new regime and manage these price risks through adoption of proper risk management measures. These measures also need to be adopted under stringent regime of well-defined and well-elaborated hedge policies with prior approvals of the Boards or the managements of the companies.

In fact, The Reserve Bank of India, in its latest issue (December 2022) of its Financial Stability Report has, once again, focused on volatile commodity prices as a source of risk in the Indian economy. The central bank categorizes this risk in the 'high risk' category, ranking it the 4 biggest risk (out of 32 identified risks) in the Indian financial system.

Especially in manufacturing industries with high demand for energy or raw materials, companies use commodity derivatives to stabilise production costs and protect operating margins. Infact commodity derivatives have generally been considered ideal risk management tool for companies to avoid violent fluctuations in commodity prices.

Price Insurance - Effective Energy Price Risk Management

Currently under the regulatory regime of SEBI, we have flourishing commodity derivatives exchanges which provide future and option contracts across commodities, including crude oil and natural gas. These domestic commodity

derivative exchanges infact serve as an ideal platform especially for hedging internationally linked commodities like crude oil and natural gas contracts. These cash – settled energy contracts are highly robust and vibrant contracts providing transparent and efficient risk management mechanism. Just to cite example of liquidity, at MCX the Average daily volume of Crude oil contracts (including futures and Options) stood at 82 million barrels in Q1 FY24 as against 42 million barrels in FY23. In value terms, Average Daily Turnover was Rs. 50,186 crores in Q1 FY24 as against Rs. 29,608 crores in FY23. Similarly, the Average daily volume of Natural Gas contracts (including futures and Options) stood at 534 million MMBtu in Q1 FY24 as against 241 million MMBtu in FY23. In value terms Average Daily Turnover was Rs. 10,827 crores in Q1 FY24 as against Rs. 11,132 crores in FY23.

Some of the other benefits of hedging in Indian Commodity Exchanges like MCX are:

- Natural forex hedge
- Low Impact cost
- Time zone advantages
- Energy contracts designed are as per domestic market requirements.
- Basket of variants (Crude oil: 100 bbls & 10 bbls, Natural Gas: 1250 MMBtu & 250 MMBtu)

While some of the large companies prefer to hedge on global exchanges for different reasons, the commodity derivatives in Indian markets provide a good platform for other large companies, small and medium enterprises to hedge their price risk while ensuring sustainable cost of operations, lighter regulatory compliances and efficient profit margins.

Regulatory Initiatives

Indian statutory bodies and regulators have also initiated many steps to encourage good risk management practices, especially commodity price risk. One such step has been SEBI (Listing Obligations and Disclosure Requirements) Regulations, 2015, which now require the listed companies to disclose the information related to commodity price risk in their Annual Reports, as one of the mandatory components of Corporate Governance Report (Schedule V, C(9) (n) and C (10) (g)). The table is as below:

Table 1

Exposure of the listed entity to commodity and commodity risks faced by the entity throughout the year

a. Total exposure of the listed entity to commodities in INR

b. Exposure of the listed entity to various commodities:

Commodity Name	Exposure in INR towards the particular Commodity	Exposure in Quantity terms towards the particular Commodity	% of such exposure hedged through commodity derivatives				
			Domestic Market		International Market		Total
			OTC	Exchange	OTC	Exchange	

c. Commodity risks faced by the listed entity during the year and how they have been managed.

Another big step in this direction is India's commitment towards the convergence of Indian accounting standards with IFRS and adoption of Ind AS in a phased manner. The new accounting standard – Ind AS is providing a new direction to all the corporates to make hedging an economically sustainable activity as opposed to plain vanilla hold. Ind AS 109 – Financial Instruments has widened the range of situations to which one can apply hedge accounting and the rules are now more practical, principle based and place greater emphasis on an entity's risk management practices. On the other hand, Ind AS 107 - Financial Instruments: Disclosures, requires entities to provide comprehensive quantitative and qualitative disclosures in their financial statements.

Way Forward

After the global business synergy effect made inroads in India, it encompassed every aspect of the country's business environment, which brought about the need for aligning operational and business strategies in line with international practices. So, it is imperative that be it at any stage i.e. project planning, commencement of operations or an experienced corporate business, the aspect of hedging can never be overlooked, as it is an integral part of the commerce and trade universally.

For ensuring & enhancing their competitiveness, the industries need to hedge their commodity price risk and the relevant risk management instruments are available in Indian markets. It is generally a global phenomenon that mandatory regulations supplemented by detailed guidelines always work better and the same needs to be applied developing a risk management culture in the India's oil & gas sector.

Considering India is inching and evolving towards this global practice of price hedging, the future may see energy price risk management emerging as a critical differentiator of business performances especially in terms of production costs, product pricing and the resultant earnings. Price risk management definitely needs to become an integral part of corporate parlance and boardroom agendas. And the day is not far when India will be able to accomplish the laid-out objectives under G20 Presidency of energy security, energy transition and sustainability leading to achievement net-zero commitments.

References:

PPAC, PIB, IEA, BP Statistical and media reports

14

Volatile Global LNG Market: Impact on India

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Introduction

The global liquefied natural gas (LNG) market saw major volatility during the COVID-19 pandemic. But it was the Russian invasion of Ukraine that ushered in a new normal. It raised concerns in the narrative about the feasibility of natural gas as a bridge fuel and broke the myth of the fuel being a low-cost alternative.

The alterations in the global LNG market have impacted consumption in several emerging economies, including India. Extreme climate events, such as the heatwaves in Europe and flooding in Asian economies like Pakistan, exacerbated the LNG market's demand-supply imbalance. The associated response of an increased understanding of climate catastrophes and the urgent need to take major decarbonisation measures might not augur well for the LNG market in the long term.

India, a net gas importer, also saw a decline in LNG demand. The LNG import volume decreased by 15% in fiscal year (FY) 2022-23 versus FY2021-22, even as the value increased by a whopping 27%, indicating import priciness.

This paper provides an overview of the global gas crisis and its continuing impact on major consuming countries. It evaluates the sectoral implications for India and what it means regarding the role of gas in India's decarbonisation pathway.

LNG Market Sees Demand-Supply Shifts

Global LNG markets saw structural changes after Russia invaded Ukraine and the ensuing decline in pipeline supply between Russia and Europe. LNG demand increased, led by European nations, while supply could only rise marginally, which sent prices soaring to unprecedented levels. The Japan-Korea Marker (JKM), a benchmark for Asian spot prices, recorded a single-day high of US$84.76 per metric million British thermal units (mmBtu) on 7 March 2022.

These high prices made LNG unaffordable fuel for many emerging economies, which saw power cuts and fuel switching. The high prices raised consumer bills in Europe, which also relied on alternatives like renewables and nuclear. The Institute for Energy Economics and Financial Analysis (IEEFA), in its Global LNG Outlook 2023-2027, noted that the European Union (the E.U.) is actively looking to lower gas consumption while LNG has acquired a reputation as a costly and unreliable fuel in Asian economies.

The infrastructure mismatch may also add to the demand-supply imbalances. In 2022, 31.2 million tonnes per annum (MTPA) of new import or regasification capacity came online, taking the total import capacity to 970.6MTPA as of April 2023. Meanwhile, the global LNG supply capacity or liquefication capacity was almost half at 478.5MTPA, including new capacity additions of 19.9MTPA. LNG markets also shifts in key players with U.S. emerging as one of the top exporters and pipeline exporters like Iran and Canada eyeing LNG exports.

Table 1

LNG Exporting Countries and their Natural Gas Production

Country	LNG Export (MT)	Change in Rank from 2021	Natural Gas production (mt)
Australia	80.90	-	117.50
The U.S.	80.50	⬆1	744.70
Qatar	80.10	⬇1	123.30
Russia	33.00	-	506.90
Malaysia	27.30	-	55.10
Indonesia	15.70	-	41.80
Nigeria	14.70	-	29.30

Source : IGU - World LNG Report 2023, Enerdata - World Energy & Climate Statistic Book 2023.

Institute for Energy Economics and Financial Analysis
IEEFA.org

Table 2

LNG Importing Countries and their Natural Gas Consumption

Country	LNG Import (MT)	Change in Rank from 2021	Natural Gas Consumption (MT)
Japan	73.60	⬆1	72.90
China	63.70	⬇1	272.40
South Korea	47.10	-	44.90
France	25.60	⬆3	27.80
Spain	21.10	⬆1	24.00
Chinese Taipai / Taiwan	20.30	⬇1	20.40
India	19.40	⬇3	42.20

Source : IGU - World LNG Report 2023, Enerdata - World Energy & Climate Statistic Book 2023.

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India and China emerged as top LNG markets in Asia in recent years, but high prices impacted demand. Total Asian imports went down by 22.2MT in 2022. Asian LNG importers, including India, Pakistan and Bangladesh, relied more on long-term contracts or witnessed fuel switching to cheaper fuels.

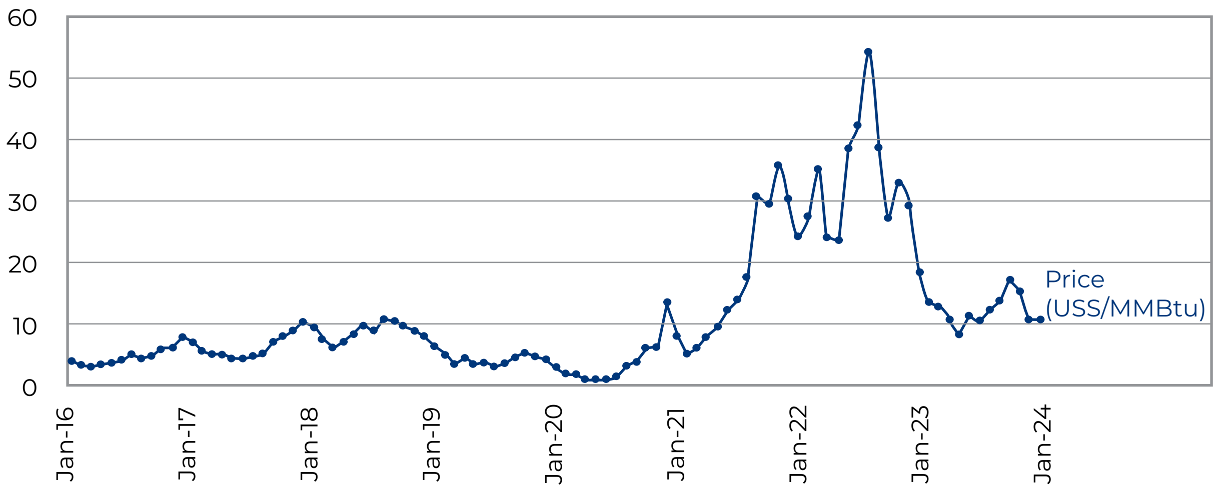
LNG demand is expected to be weak even in Europe. Gas demand fell in Europe by 13% or 55 billion cubic metres (bcm) in 2022 due to a mild winter, energy efficiency, fuel switching and increased renewable energy use, among other reasons. This will likely continue due to strong European storage levels, which were 99.6% full until May 2023 .

Price Volatility is the New Normal

Demand-supply imbalances have resulted in highly volatile LNG prices in the last few years. JKM prices touched a low of US$2/mmBtu during the pandemic, when there was complete demand demolition, to US$84.762/mmBtu on account of post-pandemic economic recovery. JKM prices are derived from the pricing of international hubs, which have also been very volatile. The chart below shows the average monthly prices, which have varied for many years but have been very volatile in the last few years.

Figure 1

JMK/Asian LNG Price (US$/MMBtu) Jan 2016 - Jan 2024



Source : CME, Monthly Average Prices

Institute for Energy Economics and Financial Analysis IEEFA.org

The structural uncertainty of LNG markets due to demand-supply balances, trade flows and seasonality could make volatile gas prices the new normal over the next decade.

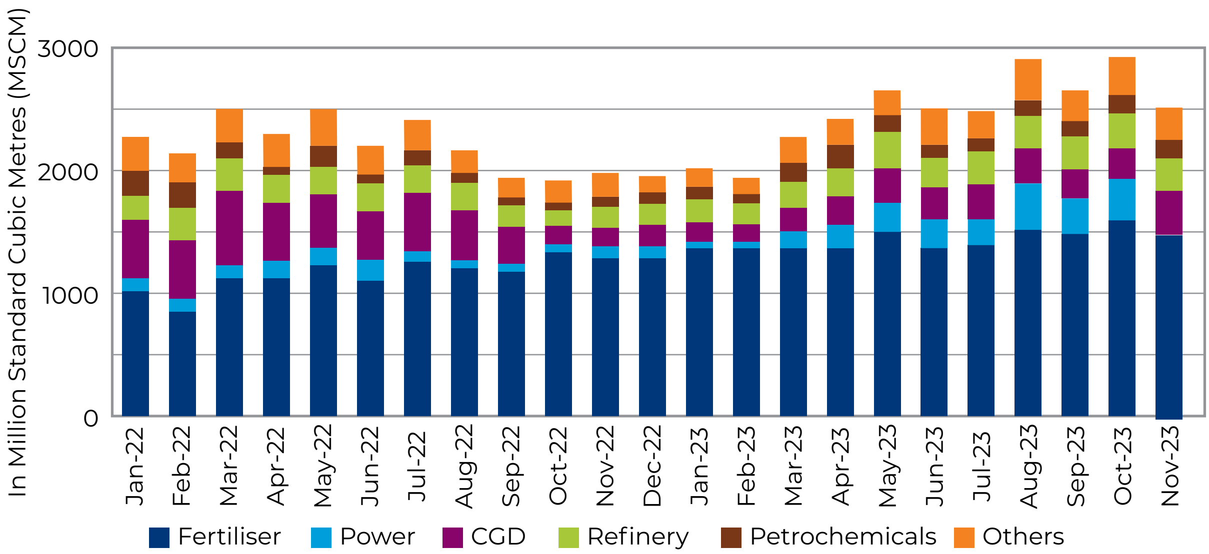
a. Demand Supply Balances: Supply or demand shocks trigger the LNG prices upwards. The Russia-Ukraine war that lowered access to Russian pipeline gas to European countries is a supply shock, while Japan's increasing LNG imports due to the nuclear shutdown after the 2011 Fukushima disaster is a demand shock. Such shocks are becoming more recurrent, adding to the LNG market volatility. High LNG prices incentivise the construction of new supply facilities to temporarily balance the market. But increased supply with high prices leads to demand destruction, causing supply gluts and lowered production again, resulting in a demand-supply mismatch.

b. Trade Flows: With higher trades on the spot market, 35% of total 2022 gas trade, LNG prices are more dynamic now, impacting global markets instead of only regional impacts. Unlike long-term gas contracts based on oil prices, spot prices use competitive prices at various gas hubs, adding to volatility. Though high spot prices rekindled a preference for long-term contracts, those are also now costlier with preference for market-based pricing.

c. Seasonality: Increased events of extreme weather conditions or milder-than-expected winters in different regions result in increased volatility in the LNG market. The recent simmering down of LNG prices stems from muted demand from Europe due to mild winters. On the other hand, in 2022, there was increased demand from Europe due to lowered Russian pipeline supply along with extreme heat conditions, reducing hydro and nuclear output resulting in high LNG prices.

Figure 2

Sectoral LNG Consumption (Jan 2022 to Nov 2023)



Source : PPAC's Monthly reports on Natural Gas Prodcution, Availability and Consumption

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Global Shifts Impact the Indian Market

The price volatility witnessed in global markets translated to the Indian market as well. The domestic price formula up until recently was based on the volume-weighted average price (VWAP) of four international benchmarks (U.S. Henry Hub, U.K. National Balancing Point, Russian domestic gas price and Alberta reference price) calculated twice a year for trailing four quarters and with a lag of one quarter. This resulted in a mismatch in domestic and spot gas prices and exceptionally high prices after a year of sustained high prices seen in 2022.

The high prices resulted in demand destruction and fuel switching in industrial and city gas distribution (CGD) sectors, which had started to emerge as key gas consumers in India. Owing to the pass-through price policy and price-sensitive consumers, CGD players could not use exorbitantly priced LNG lowering demand. A key LNG consumer was the highly subsidised fertiliser sector, with subsidies costing the exchequer about US$30 billion in FY2022-23 and budgeted to be US$21 billion for FY2023-24.

In 2023, to counter the impact of high LNG prices, domestic prices are announced monthly linked to Indian crude basket. A floor and ceiling price has been fixed for nomination fields at US$4/mmBtu and US$6.5/mmBtu for two years, post which the floor and ceiling would increase by US$0.25/mmBtu. The ultimate objective is deregulating gas prices in the medium term, notably by 2027.

While this might stabilise the domestic gas prices and usher in demand, imports meet almost half the demand which could go up to 70% if gas consumption increases.

LNG markets are going through their most geopolitically and macroeconomically unstable periods, with volatility becoming the new normal. If India continues to import large volumes of LNG, it will continually be at the mercy of unpredictable global commodity prices, leading to huge energy security and trade balance risks.

Future of Gas in India

Gas expansion in India will not be easy, especially with the requirement of expensive infrastructure investments that run the risk of becoming stranded. The country's gas demand is price elastic, but downstream gas assets are capital-intensive. Therefore, volatile prices result in miscalculations in project returns and hamper profitability. Volatile fuel prices also raise the operating costs of downstream projects in the industrial, power and CGD sectors, harming product competitiveness, utilisation rates and returns on investment. All this results in difficulty in sourcing project finance debt capital for new projects.

The domestic gas allocation priority and regulated pricing have enhanced infrastructure investment in the CGD sector. There has been an increase in CNG (compressed natural gas) stations, from 3,711 in January 2022 to 6,088 in October 2023. Over the same time, there has been an increase in the PNG (piped natural gas) connections for domestic, commercial and industrial segments by 37%, 16% and 35%, respectively. This entails a major stranded assets risk for the CGD infrastructure as with increased demand, India's dependence on LNG, which is likely to remain expensive and volatile this decade, would rise.

The fact that there is a very concerted effort to use new technologies and India being keen to gain global leadership in producing and exporting greener fuels, such as green hydrogen, will compound the stranded assets risk.

Targets for green hydrogen and green ammonia, along with the increasing awareness of natural fertilisers, could largely displace the need for urea-based fertiliser in the medium- to long-term. Similarly, the increased focus on electric vehicles and their associated infrastructure may encourage people with city driving needs to invest in a newer technology rather than natural gas. Moreover, the rapid advancement in possible range, charging speed and available charging infrastructure will make the choice easier for consumers.

Government's renewed focus on biofuels and biogas, with recent policy amendments such as the blending of compressed biogas (CBG) in the city gas grid, is expected to increase the offtake and lower natural gas use.

In such a dynamic energy environment, globally and more so in India, it is important that the useability of a fuel is well understood and defined for a longer-term period, especially one such as gas that requires massive capital investments in infrastructure. A report by IEEFA notes that 12.5 gigawatts (GW) of current gas capacity can provide peaking power and ancillary services to maintain grid quality and flexibility. Similarly, gas can promote more renewable generation and new technologies, such as battery storage, by announcing more round-the-clock tenders for renewable technologies with gas.

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Navigating India's Energy Transition: Challenges, Commitments, and Digital Innovations

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India has become a steadfast supporter of environmental initiatives, with a commitment to introducing 500 GW of non-fossil energy by 2030. The country pledged to achieve net zero emissions by 2070 at the 26th COP on Environmental Change in 2021, establishing an unabated coal-terminated power age under the Glasgow Summit. Decarbonization and the spread of clean energy are intertwined goals that highlight both challenges and opportunities.

Public Sector Undertakings (PSUs) or State-Owned Enterprises (SOEs) have ruled India's energy system for a long time, contributing to a simple transition for networks and employees. However, the primary energy use in 2021 was 1.3% above 2019 levels, with a significant gap in primary energy consumption between OECD and Non-OECD countries.

Nations like China, Japan, Germany, the United States, and Spain are also at the forefront of the exploration and implementation of clean energy programs, seeing it as a useful tool for developing new products and innovations, as well as equipping local design and development firms with the skills and capabilities needed for the sustainable energy value chain.

India faces numerous constraints at multiple ground levels, including technological, institutional, regulatory, and societal when attempting such a significant change in the energy sector. Advancements in force transmission and distribution are required due to the growing interest in financial development. New energy technology integration is essential for sustainable power reconciliation, and interoperability and operation of the system are crucial for system integration.

India's government set a goal of generating 175 gigawatts of energy entirely from renewable sources, such as wind power, solar electricity, and small hydropower. As part of its commitments for the year 2030, India aimed to achieve 40% of installed capacity from non-fossil fuel and a 33-35% reduction in GDP emissions intensity from 2005 levels.

India is one of the largest carbon dioxide emitters, ranking fourth behind China, the United States, and the EU. However, India's large population explains its lower per capita emissions compared to the United States and Russia. The country's energy value chain is evolving, with small businesses entering the market and a networked, decentralized structure in the generation sector. The power market's centralized structure will be replaced by a networked, decentralized one, with synchronized national and regional grids. Intelligent demand response will disrupt the distribution sector, and smart metering systems will reduce electricity theft. Innovations like IoT, blockchains, big data, cloud computing, robotics, automation, low-carbon energy systems, data analytics, and virtualized power plants are playing a role in the energy industry. Leading IoT adopters in the oil and gas industry include BP, Equinor, ExxonMobil, Shell, and Total Energies. The energy sector is becoming decentralized, digitalized, and carbon-free, improving the energy value chain and leading the world towards a sustainable future.

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Business Strategies for Oil & Gas Companies in India: Bio-energy & CCUS

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Oil and gas activities contribute to approximately 15% of the overall energy-related emissions worldwide, which is roughly equivalent to 5.1 billion tons of greenhouse gas emissions. Globally, there is a pressure on the oil companies to become net-zero. The Indian government has set a goal to achieve net-zero by the year 2070. Oil & gas companies play a major role in Energy Transition & are required to prepare strategies for making a transition towards a low carbon energy system. ONGC has a target of net zero by 2050, IOCL plans to achieve it by 2046. HPCL, BPCL, and GAIL have set the deadline to achieve net zero by 2040.

India remains the third largest consumer of oil, as of 2022. The nation's oil consumption is projected to grow by 40% to reach 6.7 million barrels per day by 2030 and is anticipated to rise further to 8.3 million barrels per day by 2050. Therefore, Oil and Gas will continue to be a mainstay share in our energy mix for the next two decades. Government of India has set a target to increase the share of gas in the energy mix from the current value of 6.5 per cent to 15 per cent by the year 2030 to make India a Gas based economy. Augmentation of CBG shall help in achieving this target.

In the Union Budget for the year 2023-24, there is an allocation of Rs. 100 billion for setting up of 200 CBG Plants. There are plans to mandate gas marketing organizations source a part of their gas intake (5%) from CBG.

Oil and gas companies are also giving greater emphasis to Carbon Capture Utilisation and Storage (CCUS) in their strategies and investment initiatives. CCUS is a versatile technology with multiple roles in supporting the oil and gas sector's shift towards low carbon transition.

Today bio-fuels play a significant part in the energy mix to help the world reaching towards net zero. As per analysis by International Energy Agency in 2021, Global demand for biofuels is set to rise by 28% by year 2026. With the launch of Biofuels Alliance, the real story on biofuels has started. India has revised target to achieve 20% blending of petrol with Ethanol by 2025, instead of 2030 earlier. India is looking forward to save 63 million tonnes of oil per year and US $ 5.4 billion in oil imports with this action.

The assessment of future energy transition strategies of European oil and gas companies – Shell, Equinor, BP having emission targets are focusing on transition from oil companies to energy companies whereas US oil & gas companies – Chevron and ExxonMobil chose to remain fossil focused. Shell, BP and Total Energies have also made efforts in acquiring biogas-producing companies in their countries. Biogas overlaps with existing natural gas businesses and will help in decarbonising industries and transport sector. Shell, BP, Total Energies have already started co-processing biofuels at their refineries to begin their bio-fuels journey.

India can also have similar strategies with placing bio-energy at the forefront of its transition efforts. Bio-energy sector offers exciting avenues for providing clean energy and combating climate change. India can also push for supportive policies, like increasing mandates, carbon pricing mechanisms, and tax breaks for biofuels producers. Indian OMCs can collaborate with global giants to explore innovative financing models for biofuel production, attracting investments and accelerating India's biofuel transition.

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