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COMMODITY INSIGHTS

YEARBOOK 2022

FOCUS: ENERGY

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Director

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FOREWORD

Commodity Insights Yearbook identifies substantive contemporary issues as its theme. This year, quite aptly, the theme of "energy" has been selected for in-depth research and analysis.

Energy has been a major economic, and at times political, issue for most of the nations for several decades now. But with rising geopolitical tensions it has become the economic and political issue for the entire world. Comfort levels of several nations, and in the process all global economies, have been disturbed following the Russia-Ukraine conflict and the aggravation of energy crisis in the world. Energy being fundamental to the functioning of the economic machinery, energy crises invariably permeate into all other economic activities. It gets translated into other commodity prices through forward and backward linkages. The current global inflationary spiral or even recession is a visible sign of the underlying weakness of the energy eco system. This underscores the need for maintaining reasonable level of stability in this sector, if not an equilibrium, for the smooth functioning of every economy.

Yet another dimension of the energy sector is its impact on environment and the ever rising concerns on sustainability. Though this is not a new concern, the simmering discontent on the negative effects of the non-renewable sources of energy has got magnified many fold with the rising concern on climate emergency. Energy issues have merged with emission and environment leading to several structural issues of planetary dimensions.

Considerable research, debate and deliberations are happening at a global scale on most of them, particularly under the aegis of the UN Framework Convention on Climate Change (UNFCCC) and at regional and national levels. Energy trading exchanges for enabling optimisation, carbon trading for promoting mitigation of carbon footprint through cost, market based solutions and green financing etc. are initiatives on the ground trying to find practical solutions to the issue.

The content in this Yearbook carry several policy initiatives and recommendations on the energy front. I am sure that will be useful in addressing the energy related concerns through greater awareness and action by the stakeholders.

Dr. C K G Nair
Director NISM

PREFACE

The Indian economy is currently one of the fastest growing amongst the major economies of the world. Real GDP growth was 8.7% during financial year (FY) 2021–22, and 13.5% during the first quarter of FY 2022-23. These numbers reflect a growth momentum which has overcome the challenge posed by the Covid pandemic of the last two years, and also disruptive geopolitical events like the war in Ukraine. The strong growth momentum is poised to transform India into a developed economy over the next decade or two, supported by a vibrant democracy and strong international alliances. India has now become the world's fifth largest economy, as per estimates of Bloomberg, based on IMF data.

A large and growing economy, especially a commodity-intensive economy like India's, suggests growing demand for commodities and associated services like risk management and reference pricing for commodities. The growing economy would also require a vibrant commodity sector with efficient support services like warehousing, logistics, quality assaying, etc. It is here that India's commodity derivatives markets have been playing a significant role in providing the aforementioned services and also connecting MSMEs. The Indian commodity derivatives market is itself undergoing transformational change to meet the demands of a transforming economy, supported by regulatory and policy initiatives that have been instrumental in making the market more relevant to the demands of the economy.

As the commodity markets expand and evolve, it is essential to raise awareness levels among the market players and stakeholders in commodity value chains. It is also necessary to evoke research interest in the academic community, so as to explore and create new knowledge pertaining to commodity markets. The Commodity Insights Yearbook, a joint annual publication of the National Institute of Securities Markets (NISM) and the MCX Investor Protection Fund (MCX IPF), is an ongoing endeavour in this direction, aimed at raising awareness and increasing knowledge about the commodity ecosystem among all stakeholders.

This year, the Yearbook focuses on the 'Energy' segment, and carries insightful articles on various elements relating to this segment in its Emerging Trends Section. The issues and perspectives around Energy commodities have always been of high interest, but have gained prominence in the Covid- and post-Covid period. Energy markets need to be understood well not only for grasping the significance of geopolitical events which lend great uncertainty to these markets, but also to comprehend the myriad issues which would become important in the days to come, viz. issues around green energy, electricity derivatives, electric vehicles, etc. Along with the Yearbook, useful time-series data in easy-to-use spreadsheets is also being made available on our website for free download and use by all those interested, especially researchers and analysts, to learn about commodity markets.

The Commodity Insights Yearbook is an earnest attempt to help investors, academicians and other stakeholders to become proficient and knowledgeable about this crucial and quickly developing area of India's financial sector. I am sure our stakeholders would find the Yearbook helpful and relevant, and hope that it remains the industry standard reference for commodities derivatives markets in India.

P. S. Reddy
Managing Director & CEO

ENERGY MARKETS – PROGRESS AND PERSPECTIVES

Energy is undoubtedly one of the most essential elements of the modern economy – right from the post-Industrial Revolution period till date, and is likely to remain so in the foreseeable future. By all estimates, use of energy is strongly related to almost every conceivable aspect of development viz wealth, health, infrastructure, education and even life expectancy itself are significantly related to the consumption of energy by a country's population. Even in current times of uncertain global markets, amidst rapid development and deployment of technology that is making use of physical resources increasingly redundant, the world needs energy -- and in increasing quantities -- to support economic and social progress and build a better quality of life. Hence, the chasm between the economic haves and have-nots is to a considerable extent, the divide between those having easy access to energy and those who do not. The developed countries are marked by easy access to energy which not only powers their industries, transportation and communication, but also supports cutting edge medical facilities, schools and colleges providing superior quality education and much more of such soft infrastructure. For developing nations, on the other hand, the need for reliable and affordable energy is more fundamental. It has a more critical role in improving and even saving lives. In these countries, reliable energy supports expanded industry, modern agriculture, increased trade and improved transportation. These are the building blocks that help people escape poverty and create better living conditions.

Traded Instruments in Energy

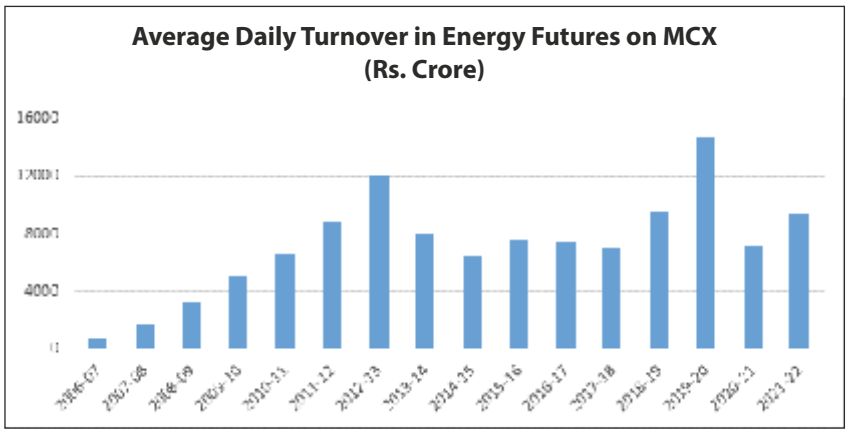
While the demand for energy is unidirectional and unequivocally connected to economic growth, there are several inter-related and complex dimensions connected to energy commodities that determine their supply and accessibility. Many factors play a role in influencing energy supply, not least of which are geographical availability of energy commodities and the availability of the right technology for efficient development and distribution of these commodities. Against this context, market institutions and innovations in financial instruments overlying energy commodities traded in marketplaces like exchanges, have emerged as solutions to address the complex dimensions of energy demand and supply.

Among such instruments, exchange-traded Futures and Options contracts in commodities like Crude Oil and Natural Gas have emerged as one of the most effective and efficient instruments for addressing two of the most vexed issues in the energy market: that of appropriate price discovery of the commodities and risk management against the highly volatile prices of such commodities. The effectiveness of these instruments in price discovery can be gauged by the fact that worldwide, the benchmarks used to quote or determine prices of energy commodities are all exchange-traded Futures in such commodities. Given the trust and acceptability they enjoy, derivative instruments are now widely available on energy commodities like gasoline, diesel fuel, propane, coal, electricity, etc. apart from crude oil and natural gas. Likewise, the popularity of financial instruments overlying energy commodities has meant that new types of instruments such as Exchange-Traded Funds (ETFs), instruments on energy Indices, etc. have also emerged

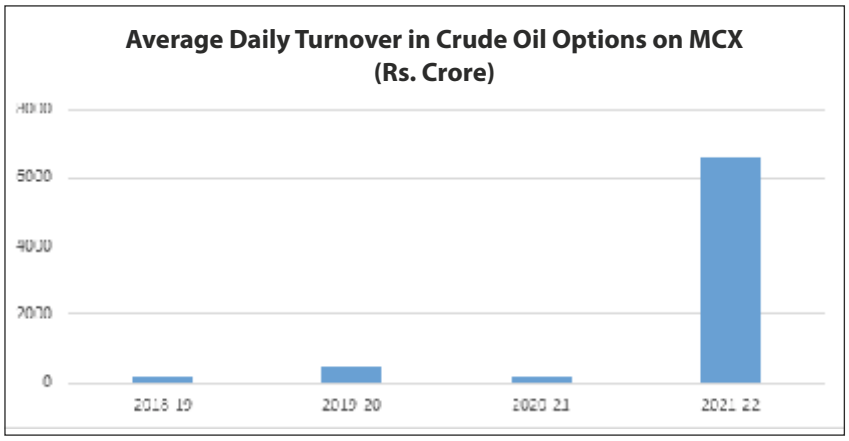
which provide investment opportunities to those looking for such opportunities in a volatile market. What's more, trade in instruments, including exchange-traded products like Carbon Credits, has long been envisaged as a viable way to balance energy needs with those of environment protection and carbon credit-based instruments offer viable solutions to address this delicate balance.

Energy Derivatives in India

The Indian market for energy derivatives has witnessed rapid expansion over the years, fulfilling the twin objectives of price discovery and risk management of stakeholders. Futures in Crude Oil and Natural Gas started being available in India since February 2005 and July 2006, respectively. Options on Crude Oil was introduced in May 2018 and on Natural Gas in January 2022. Trading volumes in energy Futures gained good momentum till 2013, dropped thereafter due to impact of Commodity Transaction Tax (CTT) introduced in that year, but again have started growing in significance in the last few years. Trends in Average daily turnover (ADT) in Energy futures in the Indian commodity market during the past one and a half decades or so, are presented in chart below:



Meanwhile, Options trading in energy commodities in India commenced with MCX launching Options on Crude Oil Futures in 2018. Subsequently, Options on MCX Natural Gas Futures were launched in January 2022. The popularity of Energy Options may be gauged from the fact that volumes in Energy Options have surpassed that in Futures now.



ADT in Natural Gas Options (launched in Jan '22) was Rs. 1168 crores during Jan – Mar 2022

While the growth of energy derivatives in India has been impressive as depicted above, the country is still behind some of the developed markets in terms of the diversity of products and instruments available for trading. Derivatives trading has to evolve in India on crude oil products, electricity, carbon credits and a host of other energy products in order to cater to the needs of diverse category of value chain participants. Investment products like ETFs on energy derivatives will also add to the efficiency and liquidity of the Indian energy markets.

From Tradability to Sustainability

Another important dimension of energy supply is the wide array of choice available to source it. A plethora of factors have contributed to development of various alternative sources of energy; such factors include environmental concerns from burning fossil fuels, depletion of some energy sources; and above all, technological advancements that make it possible to draw energy from new and renewable sources such as the sun, wind, ocean waves, underground, etc.

It is this choice of sources of energy, made possible and increasingly accessible and affordable by rapid developments in the field of technology, which is the focus of energy management across the world today. As the world makes strategies and moves towards a 'net zero' environment, all attention is focused towards substituting 'dirty energy' sources with those which are renewable, environmentally benign and therefore, sustainable. Indeed, one of the 17 goals under the UN Sustainable Development Goals (SDGs) is 'Affordable and Clean Energy' and the UN notes that "…energy efficiency continues to improve and renewable energy is making impressive gains in the electricity sector." In fact, India has taken a major lead in renewable energy use and by March 2022, renewable energy formed a quarter of India's total power capacity and

accounted for 13% of the country's electricity generation.

While India is also moving along with the developed countries in terms of the technologies being deployed to harness greener modes of energy, the country also needs to evolve newer market mechanisms to transfer risk and investments so that acceptance among energy producers and buyers also keeps pace.

Presenting the Yearbook with 'Energy' Theme

Some of these multi-dimensional aspects of Energy have been delved in great depths by authors in the current (2022) volume of **Commodity Insights Yearbook**. Anish De *(India's Energy Security Strategy: A Path Towards Diversity, Sustainability And Energy Independence)* discusses the options available for India to meet its cherished goal of energy security on a sustainable basis, while Nitin Sabhiki *(Role Of Exchanges In Supporting A Country's Energy Security)* brings to the fore the role of market institutions like Exchanges in achieving energy security and Rumki Majumdar *(Changing Energy Landscape In India And The Emerging Challenges And Opportunities)* highlights the challenges and opportunities that have emerged from the evolving energy scenario. The multiple opportunities and challenges connected to renewable energy have been delved by Vighuti Garg *(Prospects and challenges of harnessing renewable sources of energy in India)*, while Hanish Kumar Sinha and Pradiptarathi Panda *(Is Non Renewable Energy Still the Driver of Economic Growth)* explore the dimensions of substitutability of fossil fuels with renewable energy sources.

Creation and development of deep and participative markets for **Electricity** is high on India's policy agenda. Somit Dasgupta *(Electricity Markets In India – Mapping Their Transition And Transformation)* elaborates on the evolution of electricity markets, while Sonal Gupta *(Green Day- Ahead Market (G-DAM) In India: Need And Opportunities)* elucidates on the potential for green electricity market and Alok Pandey *(Challenges And Opportunities In Popularising Electric Vehicles In India)* presents strategies to achieve wider adoption of electric vehicles. Some observations on the rapidly changing fundamentals of the **Crude Oil** market and their impact on prices have been made by Pulkit Agarwal *(Trends in Global Oil Markets)* and Diganta Mukherjee & Subhankar Dutta *(Recent Trend in Crude Oil Price: Analysis and Observations)*, while Sankarshan Basu & Prabina Rajib *(Sinking Cost And Tying Hands: Indian Strategic Oil Reserves Are Not Sunk Costs)* share their perspectives on the benefits of maintaining national strategic oil reserves. Learnings from recent initiatives at ethanol blending of transport fuel is elaborated by Bibhudatta Rout *(Viability and sustainability of Ethanol blending in emerging Nation: An Indian Perspective)*.

Another policy push witnessed in India is towards **Natural Gas** and Rajesh K. Mediratta *(The natural gas economy in India – transitioning to a new dawn)* delineates the various aspects and the fulfillment of conditions needed to make India's transition towards a gas-based economy, successful.

EMERGING TRENDS

SPECIAL FOCUS : ENERGY

Dr. Hanish Kumar Sinha
Faculty Member, National Institute of Securities Markets

Armed with a Ph.D. in Agricultural Economics from Banaras Hindu University, Dr. Hanish Kumar Sinha has over 22 years of working experience in the field of agriculture industry and commodity warehousing. He is a Certified Sigma Six Black Belt and a successful Business Analyst. Currently he is associated with NISM as Professor of Practice.

Dr. Sinha was earlier associated with National Bulk Handling Corporation, leading the Commodity research team, and with National Collateral Management Services Limited. He also has vast research experience in the Commodity broking industry. He has made notable contributions across print and electronic media as a 'Commodity Expert' and has shared valuable insights with regard to commodity markets on various business channels and print media.

Dr. Pradiptarathi Panda
Faculty Member, National Institute of Securities Markets

Dr. Pradiptarathi Panda is Assistant Professor at NISM, having a decade of experience in teaching and research. He holds a Master's in Finance & Control (MFC) from Berhampur University, an M.Phil. in Finance from Pondicherry Central University and Ph.D. in Finance from the University of Mumbai and has qualified UGC NET. His Ph.D. thesis "Stock Market Spillovers: Evidence from BRICS Countries" won the Best Doctoral Thesis Award at the IIF International Conference and Award Summit 2021, organized by the Indian Institute of Finance.

His areas of research interests include International Capital Markets, Market Microstructure, Derivatives, Interest Rate Futures, Innovative financial instruments, and Financial Economics. He is a Guest Editor for Asia Pacific Financial Markets and co-editor for Review of Pacific Basin Financial Markets and Policies. Dr. Panda has published a number of research papers in ABDC, Scopus, and ABS index journals.

Is Non Renewable Energy Still the Driver of Economic Growth?

The per capita consumption of energy decides the standard of living of the people of a country. The significance of energy use as the most important barometer of economic development cannot be overstated. Tracing the temporal and spatial trends in both demand and supply of two most popular energy sources – viz, Crude Oil and Natural Gas, the link between economic development and energy demand is firmly established. We also conclude that Crude Oil and the Natural Gas would continue to be the significant drivers of the economic growth of the world, notwithstanding the great emphasis being given worldwide to shift towards green energy sources.

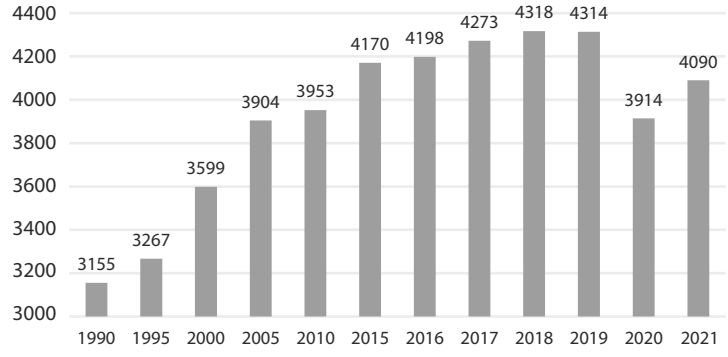
Energy continues to be the dominating factor when we talk about economic development, whether it is linked to the growth in the economy or the upliftment of the overall standard of living. In normal parlance, the economic growth of the country is considered to be directly proportional to the level of energy consumption. The per capita consumption of energy decides the standard of living of the people of a country. The whole world is running behind energy to expand their power and help to grow their economy. Natural energy is mainly derived from crude oil, natural gas, and coal. Crude oil and natural gas are more significant for a country in terms of increasing productivity in all sectors including agriculture, industry, manufacturing, and service. Energy provides services for transportation, mineral extraction, education, industrial production, storage and food production, health, cooking etc. No economy can develop without energy resources.

More than 40% of the world's oil supply comes from the USA (20%), Saudi Arabia (11%), Russia (11%), Canada (6%), China (4.99%), and Iraq (4.15%). More than 34% of total global oil is consumed by the USA (20.55%), China (14%), India (5%), Japan (3.74%), and Russia (3.70%)[1]. More than 60% of the world's natural gas production comes from USA (23%), Russia (17.40%), Iran (6.40%), China (5.20%), Qatar (4.40%) and Canada (4.30%)[2]. The nations which are producing more crude oil and natural gas are more powerful countries compared to other countries. Covid 19 has resulted in the slowdown of the production and consumption of crude and natural gas across the globe due to economic slowdown and lockdown by all the countries. In this context, we have tried to analyse the demographic presence, price discovery, behaviour in terms of demand and supply chain of crude and natural gas production and consumption across the World.

Demographic Presence of Crude Oil

Figure-1 presents the World crude oil production over the years from 1990 to 2021. The oil production has been keeping on increasing at a faster rate till COVID. During COVID, the same declined sharply by 9.27%. But, going forward, after the invention of the COVID Vaccination and the lifting of shutdown and lockdown, crude production has been increasing sharply. The average percentage of crude oil increased by 2.5% from 1990 to 2021 in which the highest production growth period was from 1995 to 2000 with 10.16%, and from 2000-2005, it was 8.49%. The lowest production growth was from 2019-20 with -9.27% and 2018-19 with -0.09%.

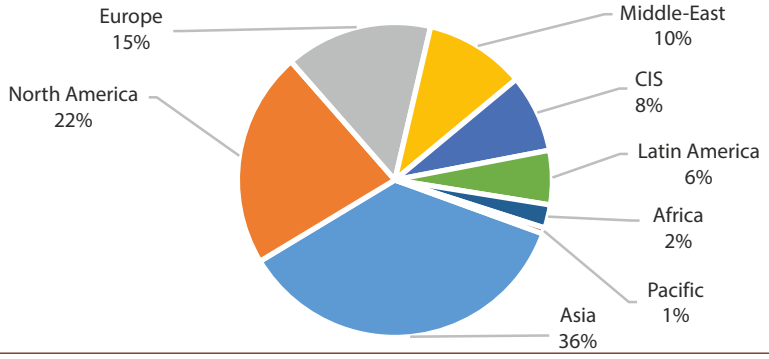
Figure -1: Crude Oil Production over the Years (MT)



Source: authors calculation/www.enerdata.net

Figure-2 presents the percentage contributions of each region to the total production of crude oil in 2021. The Asian region is leading with 36% contribution followed by North America (22%), Europe (15%), Middle East (10%), CIS(8%), Latin America (6%), Africa (2%) and pacific(1%).

Figure -2: Region wise Production of Crude Oil (2021)

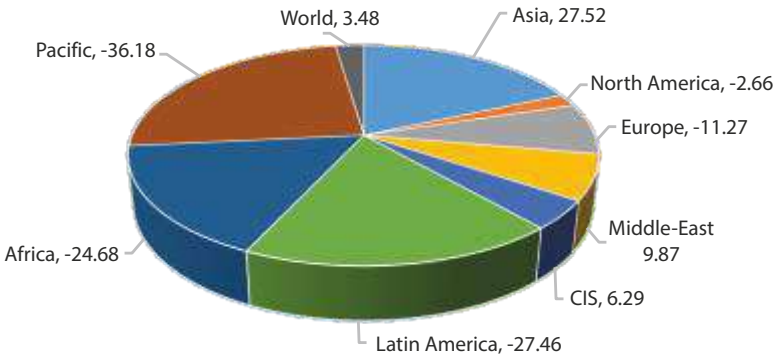


Source: authors calculation/www.enerdata.net

1 Source: https://www.eia.gov/tools/faqs/faq.php?id=709&t=6
2 Source: https://www.visualcapitalist.com/which-countries-produce-the-most-natural-gas/

Figure -3 presents the region-wise production of crude oil growth from 2010 to 2021. Asia region has seen the highest growth in to total crude oil production over 11 years followed by Middle East (9.87%), CIS(6.29%) and World (3.48%). However, all other regions have negative production growth in the same period in which Pacific being the highest (-36.18%) followed by Latin America (27.46%) and Africa (-24.68%).

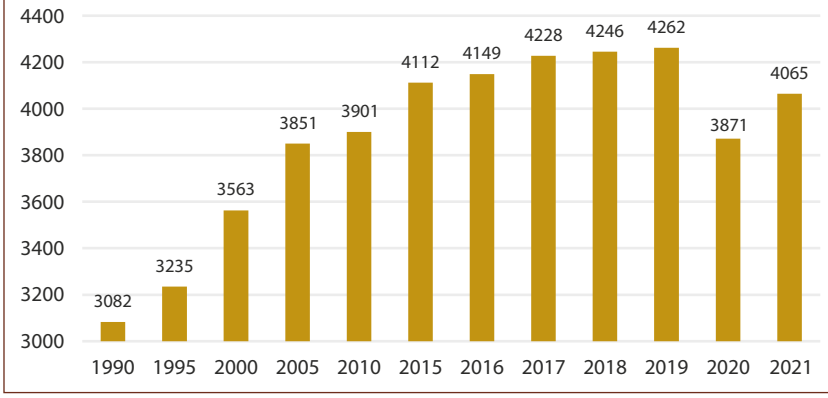
Figure-3: Crude oil Production growth 2010-2021



Source: authors calculation/www.enerdata.net

Figure-4 presents the World crude oil consumption over the years from 1990 to 2021. In line with the production, consumption over the years was also sharply increasing. The average percentage of crude oil consumption in the world during this period was 2.67% in the COVID period i.e. 2020 has seen lowest consumption -9.18% due to the shutdown and lockdown of all the activities. The highest consumption of crude oil was there in the year 2000 as compared to 1995 with 10.13% growth followed by 2015 with 5.43% and 2021 with 5% growth. The crude oil consumption in 1990 was 3082 MT and has increased to 4262 MT in 2019. However, the same has declined to 3871 MT during 2020 and increased to 4065 MT in 2021.

Figure-4 : Crude Oil Consumption over the Years (MT)



Source: authors calculation/www.enerdata.net

The region-wise contribution of the total crude oil consumption in 2021 has been presented in Figure- 5. In 2021, 73% of total world crude oil consumption came from Asia (37%), North America (21%), and Europe (15%). The lowest crude oil consumption regions were the Pacific (2%), Africa (5%) and CIS (5%).

The 11 years of region-wise growth for crude oil consumption is presented in Figure 6. In line with the production growth during 2010-2021, Asia region is also having highest consumption growth with around 30%, followed by Africa (21.95%) and Pacific (9.27%). However, North America, Europe and Latin America region's crude oil consumption have declined by -9.78%, -11.21% and -10.10% respectively.

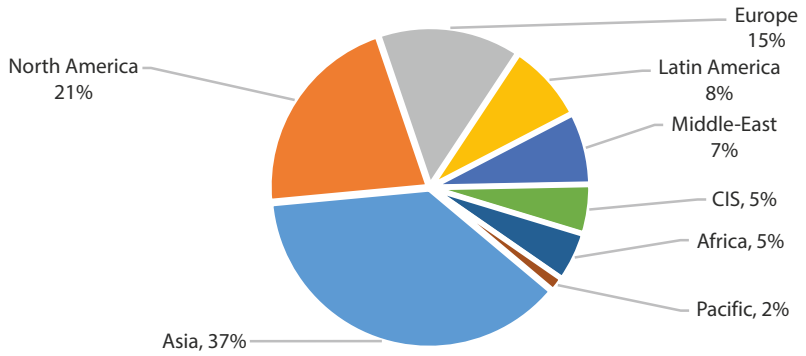
Demographic Presence of Natural Gas

The natural gas production from 1990 to 2021 has been presented in the Figure-7. The production has been increasing at a faster rate. In 1990, the natural gas production was 2057 BCM which has doubled in 30 years and reached 4176 BCM by 2021. COVID has impacted all sectors due to shutdown of all activities. However, the natural gas production was not that much impacted as the production due to COVID has fallen down by only -2.5% in 2020 as compared to 2019 and further it has grown up to 4% in 2021 compared to 2020. The growth in natural gas production was 21.4% during 1990-2000; 31.2% during 2000-2010; and 22.6% during 2010-2020. In the last five years the growth in natural gas production is around 11%.

Figure 8 presents the region-wise percentage contribution of the natural gas to world Natural gas production. We find highest contribution comes from North America (28%) followed by CIS (24%), Middle East (16%) and Asia (12%) to the world's natural gas production. The lowest contribution to the world natural gas production regions are Pacific (4%), Latin America (5%), Europe (5%) and Africa (6%).

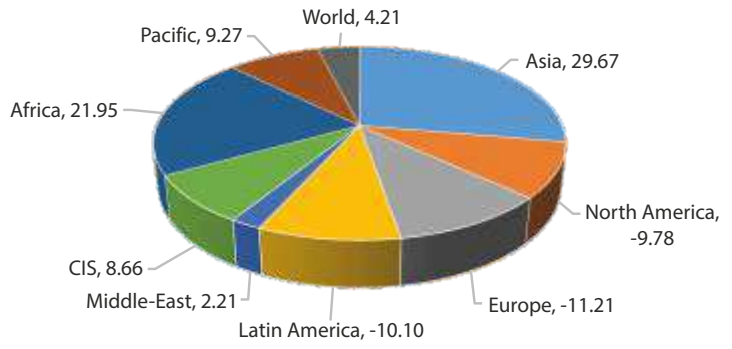
The region wise natural gas production growth in last 11 years presented in Figure-9. Pacific region has seen highest growth in production (175%) during this period followed by North America (53.31%), Middle East (44.90%), World (27.5%) and Africa (27.5%). However Latin America (-35.44%) and Europe (-9.71%) has realsied the negative growth in the production of natural gas.

Figure-5: Region wise Consumption of Crude Oil (2021)



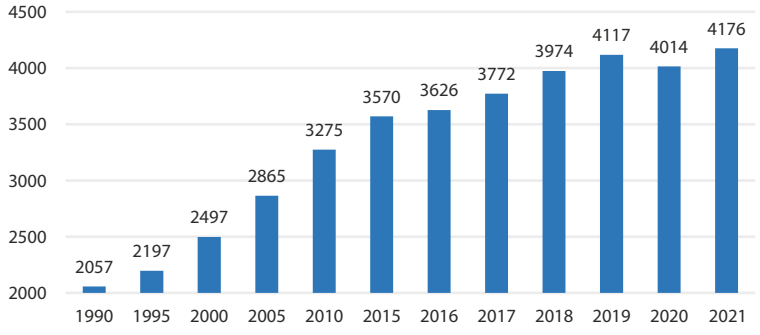
Source: authors calculation/www.enerdata.net.

Figure-6: Crude oil Consumption growth 2010-2021



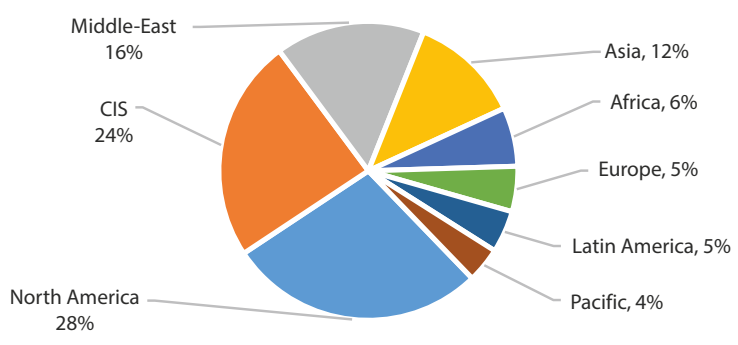
Source: authors calculation/www.enerdata.net.

Figure-7: Natural Gas Production over the Years (BCM)



Source: authors calculation/www.enerdata.net.

Figure-8: Region wise Production of Natural Gas (2021)



Source: authors calculation/www.enerdata.net.

Figure 10 presents the natural gas consumption across the world since 1990 to till 2021. In line with the production, the natural gas consumption has also substantially increased. In the period of last three decades natural gas consumption has increased by 104% in which the initial 10 years seen 22.35% (1990-2000). During 2000-2010, natural gas consumption has increased by 32.54%, and from 2010-2020 the same increased by 20%. The last five years (2017-2021) have seen 11.2% growth in natural gas consumption. The COVID has not impacted much to natural gas consumption as the same was down by 1% in 2020 as compared to 2019 and, further it has been increased to 4.8% in 2021 as compared to 2020.

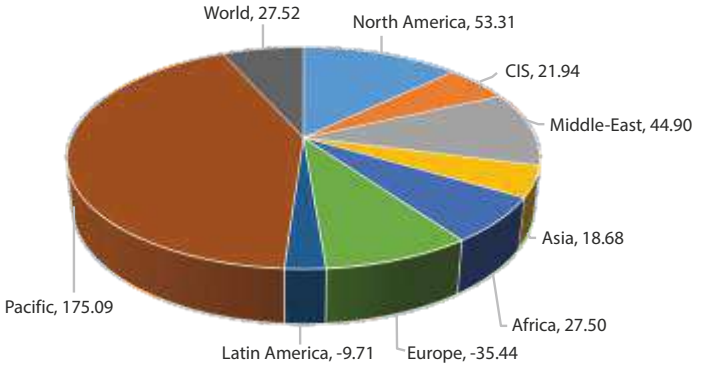
The region-wise contribution of natural gas consumption in 2021 to world natural gas consumption has been presented in Figure -11. The North American regions have contributed highest (24%) percentage of total world natural gas consumption followed by Asia (21%), CIS (18%), Europe (14%) and Middle-East (13%). The least contributor to the world natural gas regions are Pacific (1%) followed by Africa (4%) and Latin America (5%).

The last 11 years' region-wise natural gas consumption growth is presented in Figure-12. The Asia region's consumption has grown up by 56.17% followed by Africa (55.43%), Middle East (49.18%), and World (25.28%). Negative consumption growth has been realised by Europe (-5.11%) and least growth is seen with Latin America (4.20%) and CIS (12.96%).

Balance of Trade Comparison

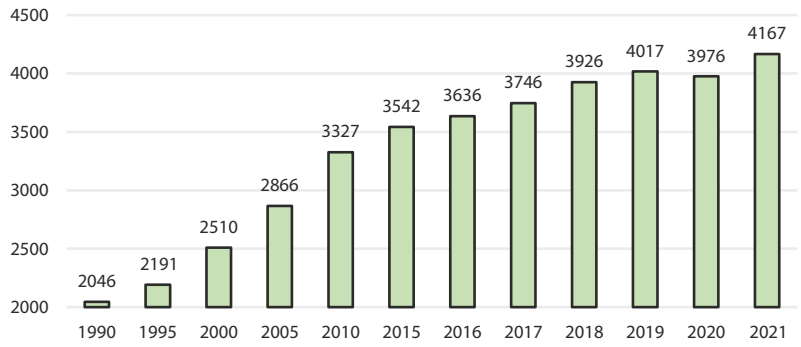
Figure 13 presents the crude oil and natural gas Balance of Trade from January 2010 to July 2020. Both Crude oil and natural gas balance of Trade has been continuing in the negative region for the last three decades. The negative region of the Balance of Trade in the two major energy products indicates that the demand has always been exceeding the supply. Though if we see the Balance of Trade situation within the two products, the demand for the natural gas has shown more positive traction in comparison to the crude oil demand which is seen hovering around the zero line.

Figure-9: Natural Gas Production growth 2010-2021



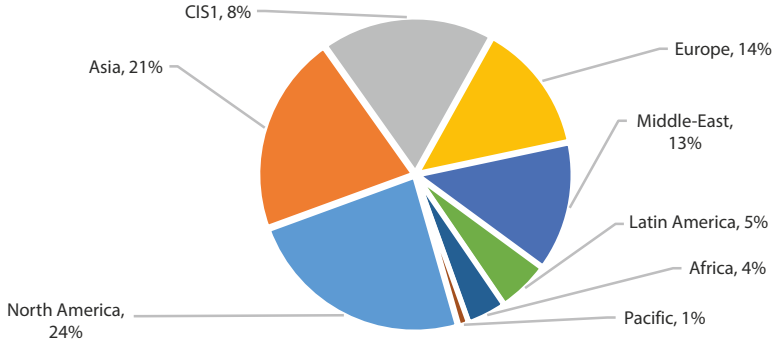
Source: authors calculation/www.enerdata.net

Figure-10: Natural Gas Consumption over the Years (BCM)



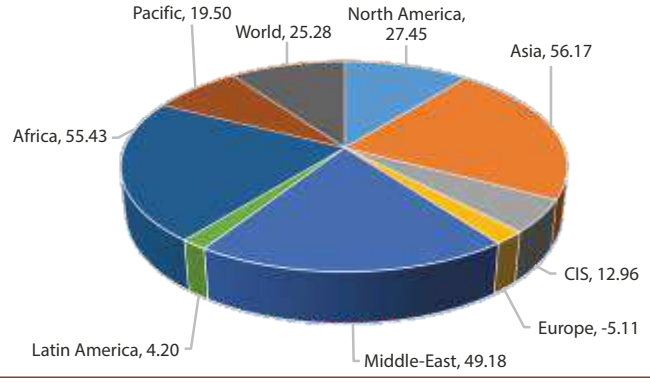
Source: authors calculation/www.enerdata.net

Figure-11: Region wise Consumption of Natural Gas (2021)



Source: authors calculation/www.enerdata.net

Figure-12: Natural Gas Consumption growth 2010-2021



Source: authors calculation/www.enerdata.net

The New Age Energy Scenario

The dependence on energy has always been the indicator for the economic growth which is been very evident from the per capita energy consumption difference between the developed and the underdeveloped countries. Primary global energy consumption grew by 5.5% last year to a new all-time high. This represented the fastest energy consumption growth since the early 1970s, and is a reflection of strong global demand bouncing back from 2020's Covid-19 energy consumption decline. Fossil fuels accounted for 82% of primary energy use last year, essentially the same as in 2020, but down from 83% in 2019 and 85% five years ago. The remaining share of primary energy use consisted of hydroelectric power (6.8%), renewables (6.7%), and nuclear power (4.3%). But now with the increased incidence of global warming and increased environmental concerns, the arbitrary use of energy resource from natural sources is increasingly becoming difficult for the developing countries to compete with the developed countries. The process of adoption of green energy like renewable energy or energy sources with lesser carbon emission comes with costly technology, which is normally beyond the reach of the developing countries, forcing the energy usage gap to widen further. On the energy wise consumption front, renewable energy continues to grow rapidly. Finally, as the world continues to electrify its transport systems, there will be a substantial increase in demand for electricity. Renewables will be called upon to bear an increasingly

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As the world continues to electrify its transport systems, there will be a substantial increase in demand for electricity. Renewables will be called upon to bear an increasingly heavy load as the natural resources are already under pressure.

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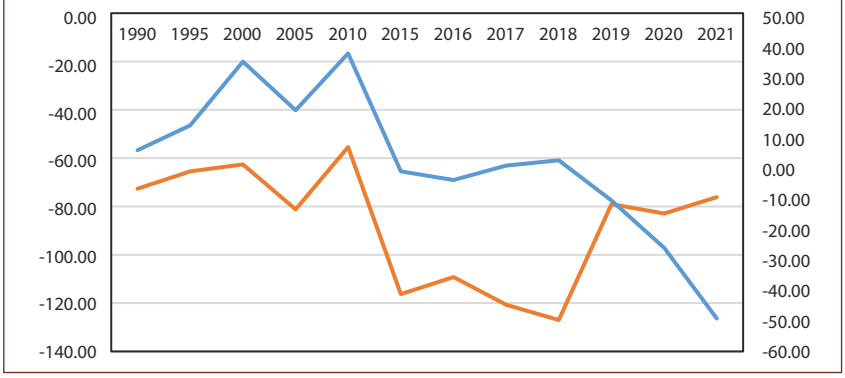
Factors Affecting Energy Supply & Demand

The demand for energy consumption is ever-increasing as it plays an important role in the lives of humans and in the activities of the economy, both as a scale of economic and social development and as a basic human need. As global population increases, the rate of energy consumption also increases as there is a need to increase water, food and energy supplies. There are many factors that can influence the price of energy as detailed below.

Energy from nuclear, coal, gas, oil, and renewable sources reacts quickly in response to the available supply. This is a key contributing factor to price fluctuations, which can occur on an hourly basis. Demand for heating, cooling, light, and processes varies in response to demand in terms of economic, technological, and efficiency measures. This is a term for energy "inventory" (since you can't store electricity), i.e. the difference between supply and demand. Gas injections and withdrawals are announced weekly, and prices adjust accordingly. The predicted weather forecast, as well as actual weather events, is an important consideration, affecting spot market prices. While seemingly more localized, some changes in the energy source can have a broad effect on the markets as the retirement of older plants as they require re-licensing can cause price fluctuations, conversions of coal plants to natural gas to avoid scrubbing-technology costs can also cause fluctuations in energy availability and prices. In the transport industry, there are severe constraints in gas pipeline

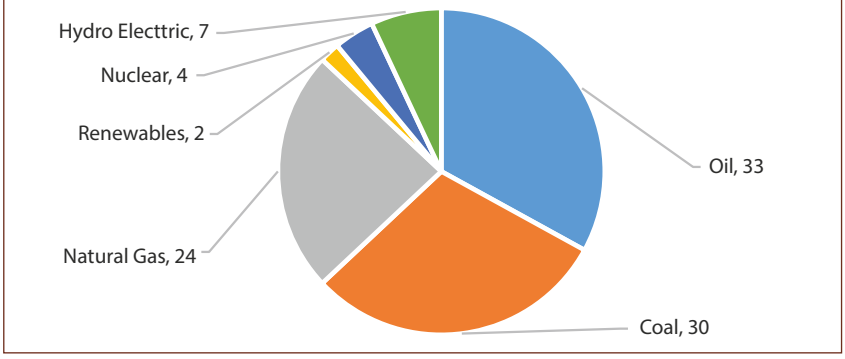
The demand for energy consumption is ever-increasing as it plays an important role in the lives of humans and in the activities of the economy, both as a scale of economic and social development and as a basic human need.

Figure-13: Comparitive Balance of Trade



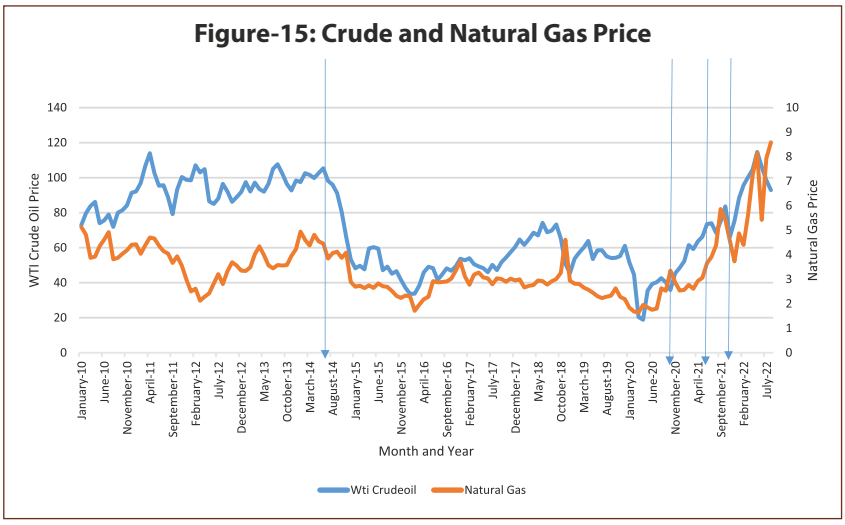
Source: authors calculation/www.enerdata.net

Figure-14: Different Sources of Energy



Source: authors calculation/www.enerdata.net

Figure-15: Crude and Natural Gas Price



Source: authors calculation/www.enerdata.net

and electrical transmission capacity, which take time and investment to reverse which can have serious implications for energy prices. Despite the massive growth in shale gas production, major changes in global oil supplies can have significant impact on the prices. The regulatory policies of major exporting and the importing nations can change both supply and demand costs quickly and significantly. Last but not the least is the financial speculation in the opaque OTC energy derivative markets, which can be the least transparent factor of all. If a market doesn't seem to be following the direction indicated by supply or demand-related factors, the cause is almost always financial speculation in the global non-Exchange-traded markets, which is largely invisible and causes unexpected movements.

Conclusion

The current growth of renewable energy is expected to expand in a rapid way which can be seen from the pattern of energy consumption in the recent times. Energy consumption trends across all categories bounced back in 2021, the post COVID times. But renewables once again led the pack. From 2020 to 2021, global renewable energy consumption grew by a whopping 15% which is an encouraging signal. Considering the exorbitant need for energy for economic expansion and social development and the dependency on the non-renewable sources of energy by over 87% and over 57% on crude and natural gas, we can conclude that the crude oil and the natural gas would continue to be the significant driver of the economic growth of the world despite the efforts being made for the promotion on the green energy with lesser carbon emission levels.

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Anish De
Global Head for Energy & Natural Resources, KPMG

Anish De is KPMG's Global Head for Energy & Natural Resources, KPMG. As an acclaimed energy sector expert, Anish has undertaken pioneering work in corporate strategy, energy sector reform and restructuring, policy and regulation, commercial and financial advisory, capital projects, energy markets, smart grids and digital. He is a key influencer through his work, social media presence and his op-eds in key publications. He has been a regular contributor to the Economic Times, CNBC, WEF, Powerline and other business and trade publications especially on matters related to energy transition, climate mitigation and adaption, technology developments on renewables, hydrogen, energy storage and on digital economy. He has also been a member of several governmental task forces and committees on energy.

By qualification Anish is a Mechanical Engineer from NIT Rourkela and an MBA in Finance from Xavier Institute of Management, India. Beyond work, Anish is an avid reader, traveler, yoga enthusiast, blogger, and animal lover. He is deeply committed to environmental causes and believes that we all would be better served if humanity was more biocentric than anthropocentric.

India's energy security strategy: A path towards diversity, sustainability and energy leadership

Energy independence is a lofty a goal to pursue, though difficult to fructify in a complex and evolving technological environment. Dependence on resources or materials outside sovereign boundaries is inevitable. Nevertheless, the pursuit of energy security remains a reasonable goal for a country like India with high imports of energy and materials, which makes us highly vulnerable. This has to be reduced to levels where geopolitics (including climate politics) or economic developments beyond Indian shores does not severely affect us and effects are controllabl.

A. Context

India is entering a period characterized by Prime Minister Narendra Modi as "Amrit Kaal". The basic premise is that the next 25 years until the 100th year of India's independence will be also its period of highest economic growth and prosperity. This premise is borne out not just of hope and ambition, but sound logic. There is momentum from the demographics of India, where young and high consuming nation could sustain economic growth for the next two and a half decades. The large young population base is also a font of resources and skills, especially on technology-enabled services where India has truly excelled. On manufacturing, there is increasing global wariness of China from a geopolitical entanglement standpoint, the political insularity and the lack of civil liberties. In a world that is becoming increasingly divided politically and economically, India stands at the middle ground, walking a tightrope, but with a seemingly firm and balanced footing. The time under the sun for a confident India could be round the corner.

Yet, this prospect of economic growth and prosperity faces some intrinsic challenges and energy is one of the key ones, the other (and related one) being the environment. Growth is energy hungry. On energy resources, India stands rather exposed. India imports more than 85% of its oil and more than 50% of its natural gas consumption. Despite sustained attempts in recent years to increase the proportion of domestically produced hydrocarbons, the outcomes have been to the contrary – India's energy imports both in terms of absolute numbers and proportion have galloped. On power production, coal has been the mainstay for long. However recent spikes in demand and the consequent supply shortages forcing high cost imports on a rather large scale have pointed to the fragility of the coal production and delivery ecosystem. In any event with the escalating concerns and activism on the environment, increase in unabated emissions from coal will be challenged. That makes new coal fired plants with current technology difficult to build.

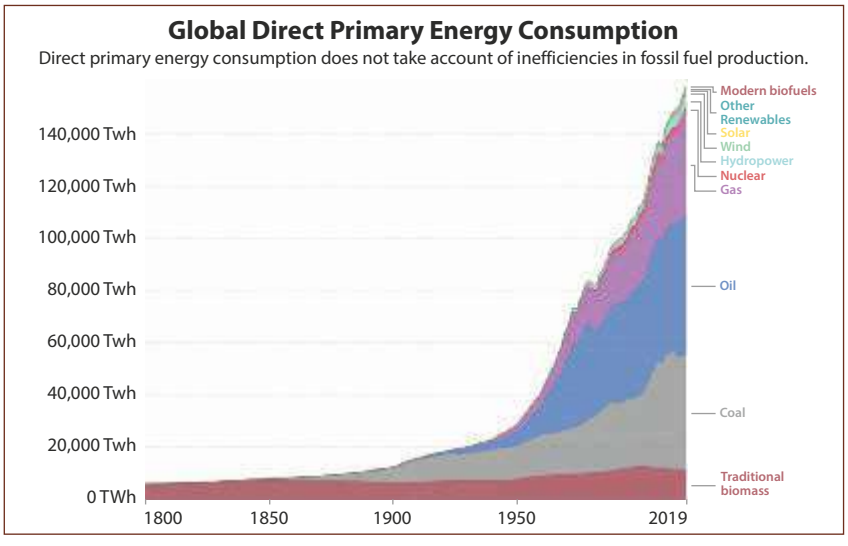
That leaves as a "go to" option clean energy resources including solar, wind, hydro, nuclear, biomass and other renewables, aided by energy storage and hydrogen. There is indeed promise on these technologies, but also a host of challenges. There is a possible path to low carbon growth through these resources but that path is complex due to innate challenges on resource characteristics, production capabilities, security, management, and a host of other related factors. That path will have to be carefully crafted out with the right intent, delivery mechanisms and governance.

Recent experiences have taught the world that the issues of energy security, affordability, environment and economic leadership are conjoined. Nowhere will this hold more true over the coming decades than in India. This paper delves into these issues and their interconnectedness. *It starts with a depiction of the global evolution of energy and resources, India's historical energy situation, progresses into the future energy resource needs, identifies tenable options and combinations to meet those needs, and portrays the challenges that will need attention. It concludes with specific views and recommendations on the policy frame for addressing the energy imperatives so that the promise and prospects of Amrit Kaal remain intact.*

Global Energy Evolution and Outlook

Global energy consumption over the past two centuries has exploded, driven by industrialization but also population growth. Much of this growth has been fuelled by fossil fuels, as Chart 1 demonstrates.

Chart 1:



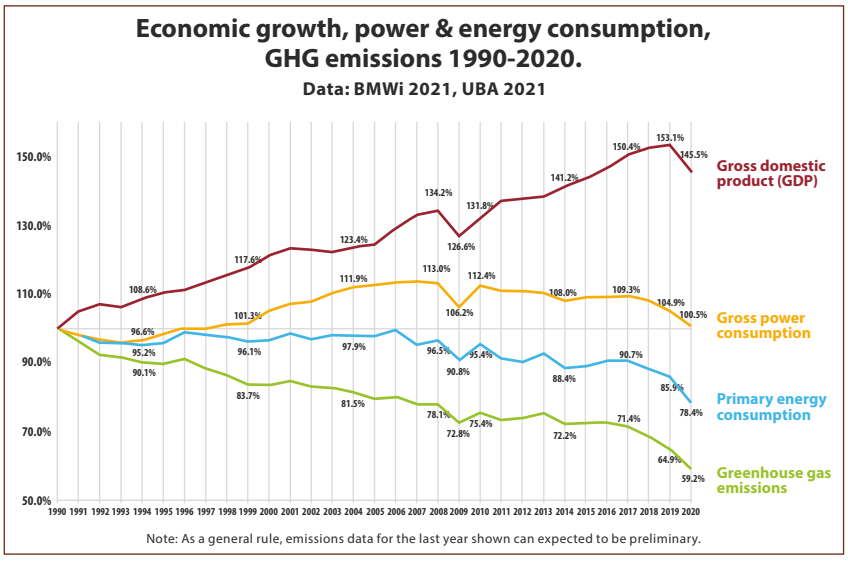
Source: Vaclav Smil (2017) and BP Statistical Review of World Energy. *OurworldInData.org/energy*

Especially over the past century, the fossil fuel economy has grown exponentially. It is only in recent times that the balance is shifting slowly towards renewable energy as costs of these alternative energy resources have fallen and technology adoption has become widespread. However, the fossil fuel economy remains deep. Despite positive action driven by climate concerns, the transition will inevitably take time. Equally, the dire situation on global warming and its effects is causing great concern in the wider society and among stakeholders. Despite the advances in technology, energy efficiency and resource management, the rapid switch required faces huge practical limitations and often conflicting priorities. This is resulting in deep global tensions, the consequence of which could be supply disruptions and/or higher prices. The coming decades would inevitably be fraught with such challenges. In particular for India, these are difficult issues due to the burgeoning energy demand and external dependence on resources, technology and equipment. For energy security it has become ever more important that India addresses these core aspects.

Taking a more recent view from Chart 2, one can see that global growth has become energy efficient. Carbon intensity has also fallen quite sharply. However, overall global growth has been robust over the past three decades leading to overall increase in CO2 emissions.

Even more importantly, accumulated CO2 over the past two centuries has now pushed the world to a point where most of the carbon budget for the planet to remain secure have already been consumed. The remaining carbon budget for remaining within 1.5 degree temperature rise will be consumed within the next ten years[1]. The consequential effects are showing up, and would likely get worse in the coming years. Especially in light of the historical inequities in emissions and development imperatives of the lesser emitters, the issue of the carbon budget will be fraught.

Chart 2:



While India has not been a major contributor to historical global emissions, it is presently the third largest emitter in the world. There would be inevitable pressures to decarbonize, which will not be easy given the structure of India's energy sector and the anticipated economic growth levels.

B. India's Growth and Energy Resources

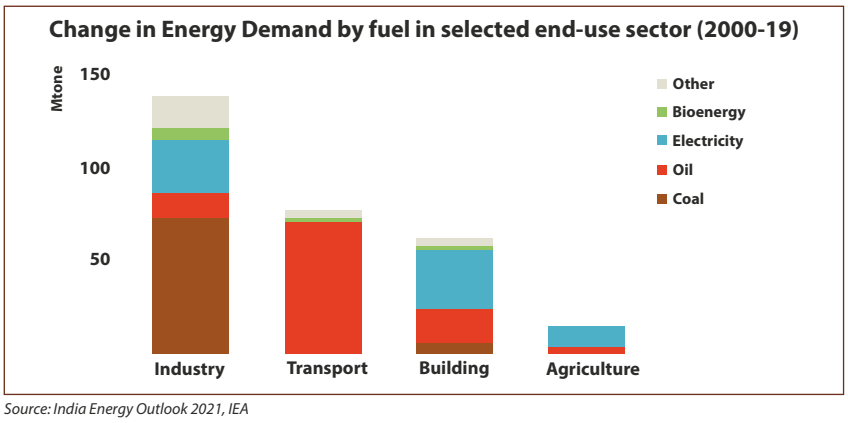
Over the past two decades the Indian economy has witnessed momentous growth. One could always compare with China and contend that the country could have done much better. While that may be true, it is equally true that the economy has transformed. In energy terms, the changes are also discernible as is evident from Chart 3.

As a point of reference, India's primary energy consumption has nearly trebled in the period 2000 – 2020[2]. Most of the growth has come from industries, followed by transportation. The buildings sector (driven by both households and the services economy) has also been a large contributor. With the prognosticated growth in industry and transportation in the coming decades, the situation will only become more challenging as India looks into its energy future.

C. The Energy Future for India

The energy future for India will mark both a continuation and a break from

Chart 3:



Source: India Energy Outlook 2021, IEA

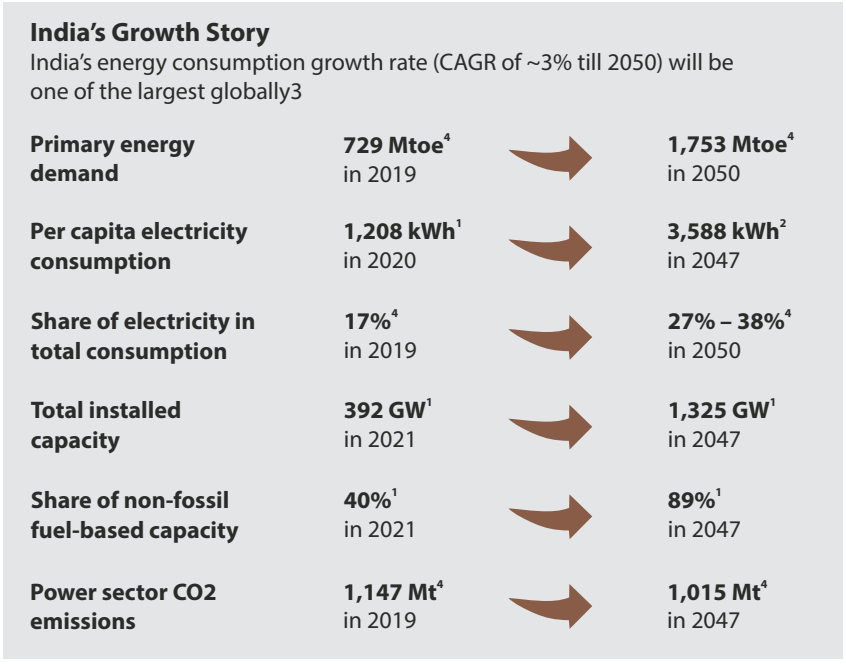
1 Estimated on the basis of IPCC 2021 report, quoted at https://www.downtoearth.org.in/news/climate-change/carbon-budget-will-exhaust-in-10-years-at-current-emission-levels-ipcc-report-78405.

2 BP Statistical Review of World Energy, 2021.

The energy future for India will mark both a continuation and a break from the past. In some ways the future vindicates the proactive policies from the past on clean energy and environment that has propelled change in the energy mix in the past few years with large scale renewable energy in the mix.

the past. In some ways the future vindicates the proactive policies from the past on clean energy and environment that has propelled change in the energy mix in the past few years with large scale renewable energy in the mix. However, India continues to depend heavily on coal at this time. This dependence at least in relative terms has to come down since as mentioned previously on account of climate concerns new coal fired power plants will be extremely difficult to finance and build. As the energy demand grows, the contribution of coal in the mix will reduce. Similarly, with electrification of transport, the share of oil will come down in mobility. An indicative picture on energy and energy commodities could be considered as indicated in Chart 4.

Chart 4:
Renewable Energy Mix



D. Focusing on the Demand Side

Decarbonising energy supply will remain a key measure for India's Net Zero journey, which PM Modi has committed by 2070. As a growth economy with an increasing manufacturing footprint, this will be nigh impossible to achieve unless there is rapid decarbonization of the demand side as well. On the demand side many of the sectors like metals, cement, mining, heavy-duty transport, etc. are characterized as hard to abate sectors. The levers in these hard to abate sectors tend to be different. Broadly, availing of the electrification opportunities will be necessary, with the electricity coming in turn from low carbon energy resources. However, there are core industrial processes in which electrification is not technologically possible or is prohibitively expensive, the focus has to move to alternative low carbon sources. The role of Green Hydrogen in particular would be very important.

Beyond green hydrogen or low carbon materials, the principles of circularity need to take centrestage. In several applications the benefits of recycling from a cost and also carbon intensity standpoint is huge. For example, recycled aluminum consumes only a fifth to a sixth of the energy as aluminum produced from virgin minerals. Similarly, recycling of waste materials including plastics and biomass can sharply bring down the carbon intensity at costs that can be at par with virgin energy materials. All of these involve technology development of various kinds and at scale. There are indeed positive trends on such technologies and what was technologically and commercially challenging a few years ago (e.g., torrefaction of plastic fluff) is now very much possible.

However, in some of the sectors, low carbon technologies and resources cannot entirely abate carbon emissions. For example, in iron and steel production, significant amount of emissions (estimated around a third of the present emissions from the BF-BOF process) are unavoidable from any of the present day production technologies including the use of hydrogen. This is where alternatives like Carbon Capture and Storage (CCS) and more importantly Carbon Capture Utilisation and Storage (CCUS) become important. For India in particular, due to the inherent limitations of geological formations that limits storage options, it will be necessary to focus on utilization more than storage.

These resources all link back to India's basic quest for energy security, affordability and transition to a low carbon energy economy. Being one of the few large global nations where there is substantial economic growth, it is in India's interest to assume technology leadership, while simultaneously defending the contention on historical inequities. India should look to lead this field through sustained investments in

research and technology development, with the intent of recycling every molecule of carbon as many times as possible, utilizing it as a resource and not as an effluent. Technology partnerships will be essential among domestic players as well as with others from across the world on fair and equitable terms. India has much to offer in terms of a large growth market on one hand and intellectual prowess on the other for these to be a win-win proposition.

Decarbonising resource links back to India's basic quest for energy security, affordability and transition to a low carbon energy economy. Being one of the few large global nations where there is substantial economic growth, it is in India's interest to assume technology leadership, while simultaneously defending the contention on historical inequities.

E. Challenges that Need Attention

The imminent change on energy has many critical dimensions. Globally, each country would be differently placed in terms of the stage of development, economic status, growth trajectory, mix of the economy, demographics, natural competitive advantages, access to resources, to name a few. It would be imperative to pair the economic and environmental dimensions together. India, in particular, with its high economic growth has some specific considerations, key among which are articulated below.

- **Innovation and Production at Scale –** Since India is on course to become a very large consuming nation in the next 2-3 decades, it is important that we lead the innovation journey. Especially since India's position on access to resources varies from other large countries, the innovation process needs to pair the purpose of innovation with the endemic resources (or to resources that India has access) to the extent feasible. In summary, India has to plan to be the innovation leader. This is very much possible. In the past decade, the innovation scene in the country has transformed as is evident through new patent applications and grants. This innovation needs to be channeled towards the purposes of economic growth and energy security.
- **Employment -** With a large young population that needs to be gainfully employed, India's priority would be to ensure that economic growth translates to jobs. The energy sector can be a very large employer provided there is domestic value addition. According to the International Labour Organization (ILO, 2012), the green transformation can generate around 60 million additional jobs, and the transition to a greener economy has the ability to impact at least half of the global workforce. This has to be planned for scrupulously and implemented rigorously, else opportunities could be missed. For example, in solar power thus far India has come to be over-reliant on Chinese suppliers for much of the value chain. This is belatedly being set right now. India would not want a repeat of this excessive dependence for other parts of the energy materials including for Hydrogen or energy storage.
- **Critical Minerals –** New age energy resources also call for new age materials including rare earths and precious metals, including Lithium, Cobalt, Nickel, Platinum, etc. which are required for batteries, electrolysers and advanced renewable energy technologies. At this time India has significant limitations on such resources being available. Globally, it is often the case that the concentration of known reserves are in a few, difficult places. Two imperatives emerge from this. Firstly, India has to secure access to the critical materials through the use of its international influence and diplomacy, much like China. The second is to develop technologies where India has endemic resources or the constraints are lesser.
- **Removing Undue Bottlenecks –** At one level India is witnessing an explosion of innovation. But at the other, critical institutions are weak and inefficient and stand in the way of development as roadblocks. This is particularly true in the electricity sector with state owned distribution companies and regulators who have failed to modernize with times and have severely stifled innovation in service delivery to users. With the increasing electrification of the economy it is of great importance that the remit of these institutions is revisited, the sector is freed from the undue distortions and barriers, and a market economy (with necessary protections for the vulnerable) is ushered in.

F. In Conclusion - Energy Independence or Energy Leadership?

"Energy independence" has often been postulated as a goal to pursue. Despite the obvious attraction of the concept, in a complex and evolving technological environment it is practically impossible to pursue energy independence as a reasonable goal. Dependence on resources or materials outside sovereign boundaries is inevitable. That said, pursuit of energy security remains a very reasonable goal. Especially for India, the high import levels of energy commodity and materials makes us extremely

vulnerable. This has to be reduced to levels where geopolitics (including climate politics) or economic developments beyond Indian shores does not severely affect us and effects are controllable. Fortunately on some renewable energy sources, India is blessed. However, energy security will call for taking a more holistic system-wide approach that covers various resources that will have to play in conjunction, the various demand sectors, infrastructure in various forms, pricing practices, regulations and markets. Energy security in its fullness is thus a very large and complex agenda.

An alternative pursuit for India could be energy leadership. This could subsume and transcend the concept of energy security. As the largest growth economy for the next several decades to come, India could aim to seize the initiative, drive advancement in technology and materials, develop manufacturing ecosystems that could not only cater to the domestic economy but also global demand and in the process lead climate action. The last element of driving climate action is important. By now it is clear that the global environment is at an extremely delicate point with escalating climate-driven vulnerabilities affecting a mass of humanity and life on the planet. Positive action on mitigating the causes and effects of climate change in these circumstances would not only be desirable, but perhaps essential. India can, and India should attempt to move the needle on climate and in turn create the future opportunities for the country. This must be planned and executed with application and determination. Key to success would be evidence-based planning and policy making, and corresponding actions to implement on the ground. That is an area which has let us down in the energy sector in the past. It is time to change that history and energise the new India.

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Head - Strategy and Markets,
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Nitin Sabikhi is Head (Strategy & Markets) at ReNew Power. Before joining RenNe Power, Mr. Sabikhi was associated with Indian Energy Exchange since its inception till April 2021, where he was strategizing and developing effective and bespoke solutions for generators, discoms and industries to enable optimized power portfolio management.

*A visiting Faculty in educational institutions such as Delhi University, IIT- Delhi, IIT-Kanpur, MDI-Gurgaon, NPTI-Faridabad, PMI-Noida, UPES-Dehradun and Great Lakes-Gurgaon, Mr. Sabikhi was a recipient of the '**Young Achiever of The Year**' and '**40 under 40**' Awards - 2019.*

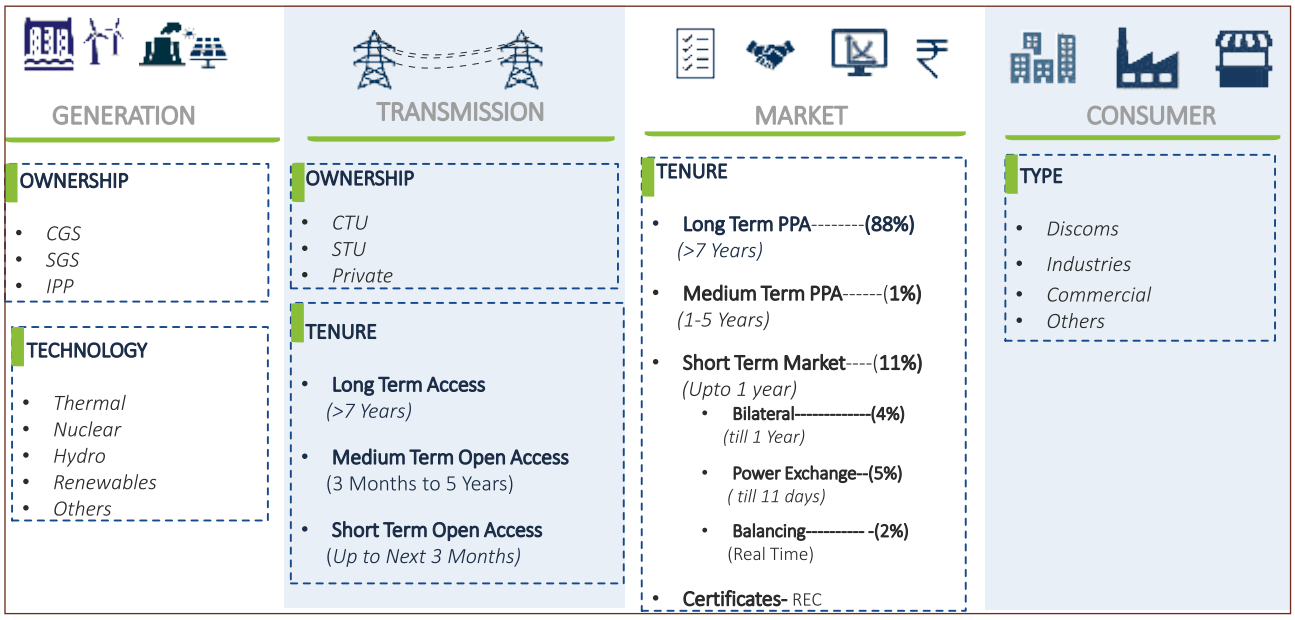
Role of Exchanges in Supporting a Country's Energy Security

Power systems across the world vary and so do their respective market designs. The big question for India now is to decide upon the best model that suits India, not just from the current system's point of view, but also from the future, renewable energy-oriented system's point of view.

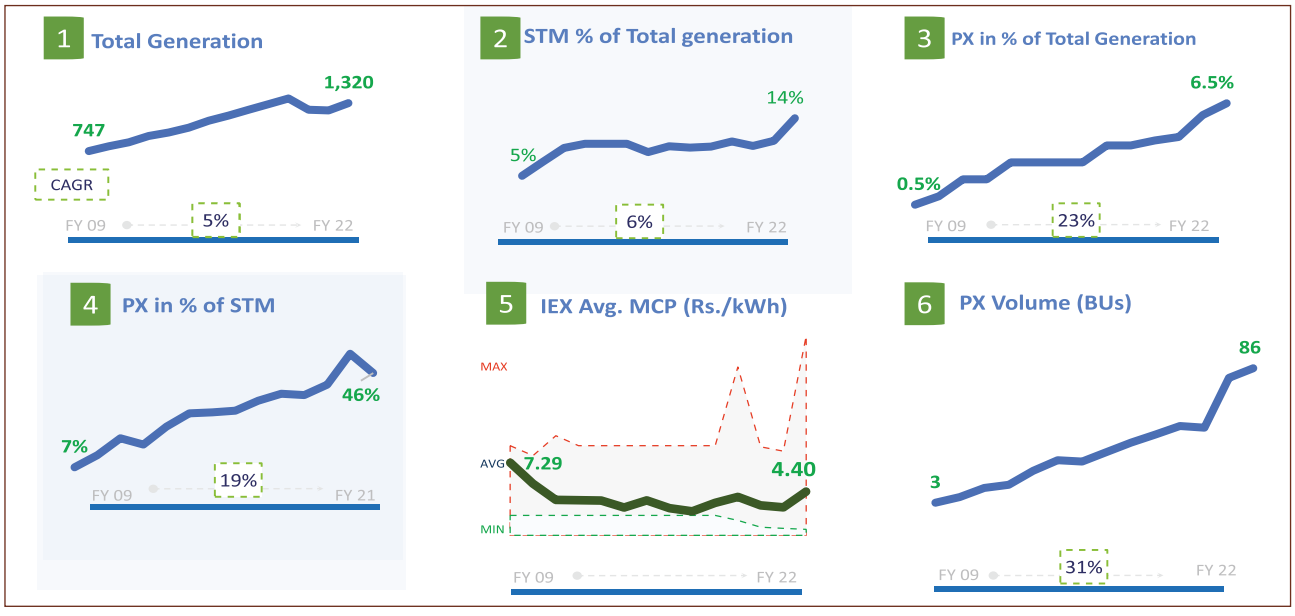
'Landscape'- Indian Power Market

Currently the value chain framework in the Indian power market comprises of physical contracts with long-term contracts being the heavyweights. Though short-term market and specifically exchange has shown high growth, long-term power purchase agreements (PPAs) comprises almost 88% of the overall total generation. Since the advent of exchange mechanism in 2008, liquidity in the short-term market has increased multifold and currently stands at around 6%. Bilateral segment accounts for nearly 4% and the Balancing mechanism (DSM) is close to 2%. The current value chain of the power sector is depicted below:

Currently value chain comprises of physical contracts with long-term being the heavy weight. Though Short-term market and specifically exchange has shown high growth.



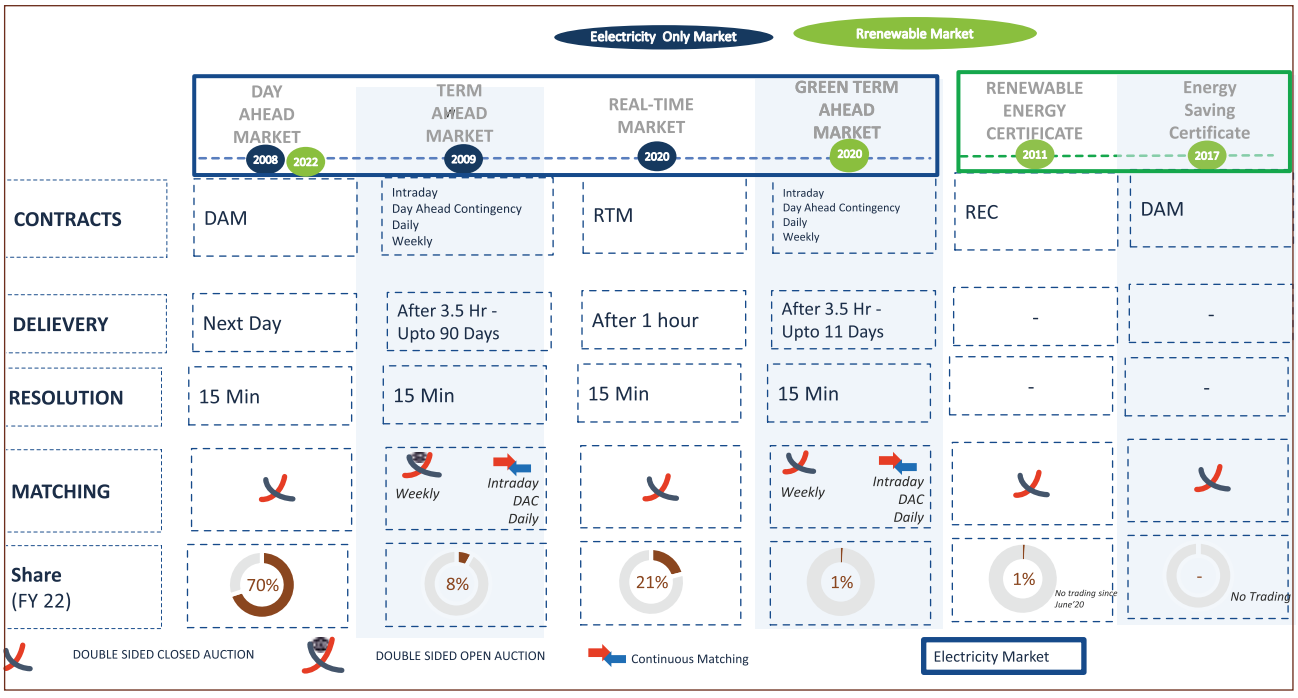
In the last decade, power generation grew at 5% CAGR whereas the exchange market witnessed a 30+% CAGR. Globally, share of exchange is much more than India and the penetration is anywhere in the range of 30%-90%. It helped the nations with deep and liquid power market to integrate renewables into their grids much more efficiently. India is now moving in that direction yet a lot more has to be done. Few key growth numbers are mentioned below:



Power exchange market in India started in 2008 that allowed participants to buy/sell electricity on a term basis for a duration of 1 day to up to 11 days ahead.

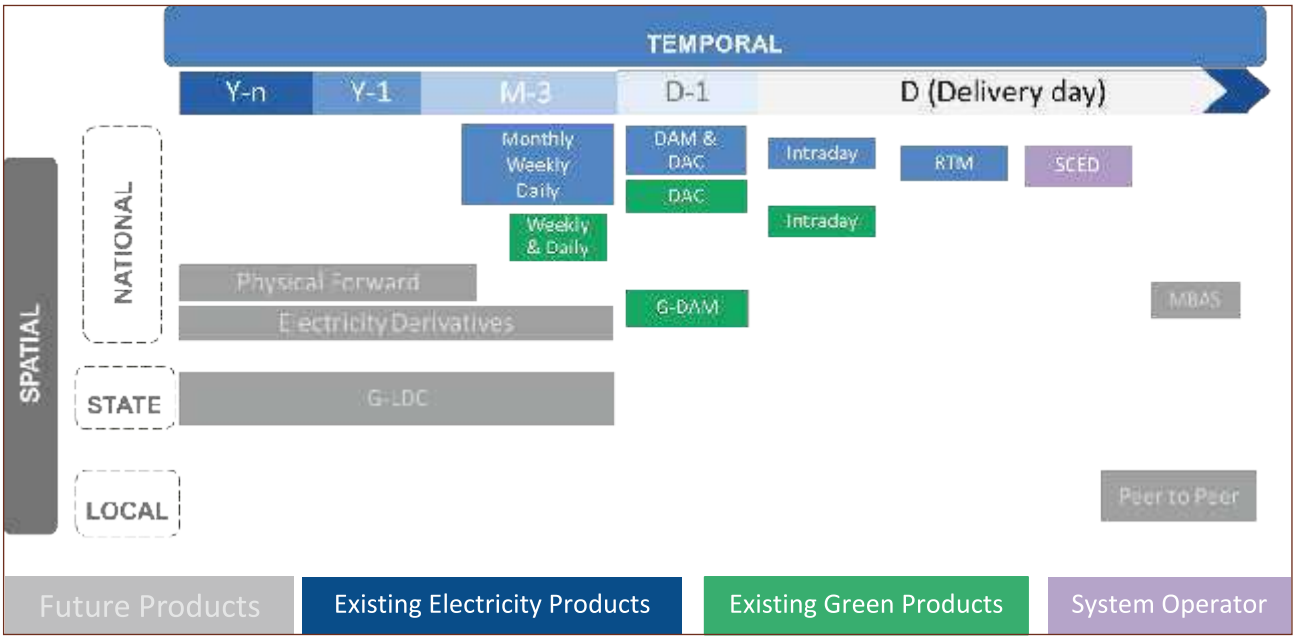
Since then, there wasn't any significant addition in the electricity product portfolio. Though Certificate market for renewables and energy efficiency were introduced in 2011 & 2017 respectively but the electricity market was confined to DAM & TAM segment. The exchange market was growing within the short-term market segment, but the overall pie wasn't increasing. It was in 2020 amid the Covid that the market was infused with two much-needed products- Real time Market (RTM) and Green Term Ahead Market (GTAM) and it was followed with Green Day ahead market in 2022. Recently the Longer Duration Contracts (LDC) upto 3 months were introduced. However, the same is yet to witness any volumes.

The different features of the electricity and certificates markets in India are summarised in the following table:



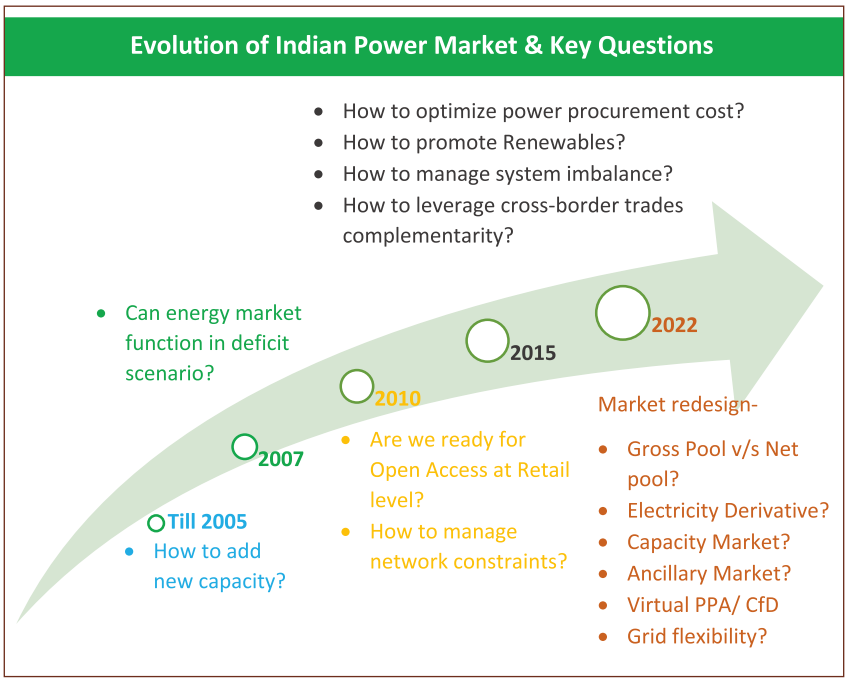
*REC trading was in abeyance

It is very important for markets to operate over a wide range of timeframes and in some cases geographies for efficient scheduling, real-time system operation and support long term investments. India power market have come a long way in the last two decades. The temporal and spatial distribution of current market is mentioned below:



'Change'- The Only Constant

In India, 'energy transition' is the most talked-about topic. However, it's not a new phenomenon and has existed since the beginning of Indian power sector, which has been transforming/ evolving with continuously changing priorities. With the world now focussing on Net-Zero commitments, Energy transition has gained lot of traction. It is important to mention that energy transition across the world is facilitated by highly liquid energy markets and India also needs to follow suit, sooner than later, to achieve its Net-zero commitments. Interestingly, the evolution or transition of the Indian power market over the past two decades can be understood from the key questions that kept changing over the course of time.



We have now entered an exciting decade with focus on integration of renewable generation into the wholesale electricity markets which needs a redesigned existing spot market with inclusion of temporal granularity, type of bids, capacity market, ancillary markets and also financial instruments.

'Learning' – Adoption of Global Best Practices or Local Innovation or Both

Power systems across the world vary and so do their respective market designs. The big question for India now is to decide upon the best model that suits India, not just from the current system's point of view, but also from the future, renewable energy-oriented system's point of view. It is important to highlight that each product has its own importance- for long term reliability, investments and resource adequacy we need '**capacity market**'. Whereas '**energy only**' market is required for optimal scheduling, the '**Ancillary market**' is needed by system operator to manage imbalances and the '**Financial market**' provides the hedge against the price volatility and support investment decisions.

When we talk about capacity market, the US adopted and implemented a lot of products/ mechanisms to compensate capacity payments. On the other hand, Europe is still debating but many European countries have either implemented or are under the process to introduce capacity market. Recent supply crisis leading to surge in prices, raised a very pertinent question: 'Can we add capacity based on this scarcity pricing or do we need a capacity market?' Besides the fact that regulatory interventions to keep price under check during the scarcity event may not be the right approach as it defers the impact, the important question of resource adequacy remains unaddressed.

Another difference between the US and Europe is with regard to Market operations being performed by system operators in US. However, Europe, like India, has a separation of system and market operators. Indian system operator, after the day ahead is concluded by exchanges, runs a Security constraints economic despatch (SCED) which is somewhat like the US design. Besides, the proposed Market Based Economic Despatch (MBED) and market coupling is a step towards building a centralized market.

'Matching principle' is another intensely debated topic. Both auction and continuous matching have their pros and cons. Auctions are run at predefined and at specific times, thus limiting the flexibility for the participants, but they ensure the most transparent price discovery. On the other hand, continuous matching provides flexibility of bidding anytime but may lead to fragmentation of liquidity and also different prices for the same period. Regulators in India are more inclined towards auction-based price discovery. Hence the participants need to develop systems which can respond to more frequent auctions in future. Given the merits, it looks like that both will play an important role in Indian power markets.

In Europe, cross-border electricity trading led to the increased competition and more efficient markets. Cross border trading in India recently started at exchanges and will certainly benefit all as it helps in attaining energy security, efficient markets by leveraging the diversity and complementarity offered by the neighbouring countries.

Grid flexibility is another important area to ensure energy security and build sustainable power systems. Exchanges through their price discovery design will continue giving the signals of system constraints that need to be addressed.

It is of paramount importance to plan and execute the energy transition as soon as possible. It is imperative to have power market redesign to

support the GoI's net zero commitments.

Flexibility- in Market & Market for Flexibility

The task for renewable energy developers has been cut out ever since the Hon'ble Prime Minister of India raised the bar for clean energy at Glasgow. We find ourselves at the cusp of history being written wherein India can assume global leadership in clean energy. We are aware that the generation capacity addition is a capital-intensive business and as the sector evolves, we are likely to see more complex constructs such as peak power, RTC, etc. gain traction over plain vanilla bids. These will require significant investments and therefore serious players should be prepared with adequate financing to capture the opportunities. We must remember that India is a leader in adoption of clean energy. 12% of our electricity mix now comprises of renewables. As the capacity addition gains momentum, we will be required to find India-centric solutions that can be replicated across the globe rather than bringing in established models and technologies here. Consistent investment in technology, research and development and market capabilities will help the sector grow substantially going forward.

It is of paramount importance to plan and execute the energy transition as soon as possible. It is imperative to have power market redesign to support the GoI's net zero commitments.

It is important to mention here that power markets are a very interesting and challenging mix of both economics and physics and it is important to ensure that the optimum balance is maintained at every given point of time. With increasing requirements of ramps, the existing market mechanism which was earlier skewed toward Day Ahead Market and slowly Hour Ahead Market or Real Time Market (RTM) kicking in, going forward, it will require products much closer to delivery, say in 5 minutes, like the US market.

The energy mix is going to change significantly and accordingly the power exchanges also need to introduce innovative bids to accommodate much complex and dynamic requirements like minimum income, ramp, upliftment payment, flexible bids etc. Besides, the market mechanism must ensure flexibility providers are reasonably compensated.

Cross border trading in India recently started at exchanges and will certainly benefit all as it helps in attaining energy security, efficient markets by leveraging the diversity and complementarity offered by the neighbouring countries.

'Uncertainty' – The New Normal

Unexpected pandemic and ongoing Russian war in Ukraine has severe implications worldwide and tossed up very tough questions around energy security, ongoing energy transition and development of the energy market. This crisis reinforced the need for resilient power system and markets. The priority of various nations keeps toggling between energy security and sustainability. However, it is an "AND" gate which is needed, not the "OR" gate.

As humans, we have learned to live and grow amid the pandemic. Similarly, the energy transition should also not wait because the climate change and its impact are continuing and needs to be agnostic to another crisis, should there be one.

It is now clear that the approach, speed, and magnitude of energy transition will vary a lot among different countries. History tells us that energy market played a very important role in integrating sustainable energy. India also needs to follow suit. However, a question is often raised: Is India moving too fast or trying too many things in the energy market space? It is important to note that we cannot have energy market of 'yesterday' catering to energy systems of 'future'.

Glossary of Terms Used

PPA	–	Power Purchase Agreement
DSM	–	Deviation Settlement Mechanism
CGS	–	Central Generating Station
SGS	–	State Generating Station
IPP	–	Independent Power Producer
CTU	–	Central Transmission Utility
STU	–	State Transmission Utility
REC	–	Renewable Energy Certificate
Discom	–	Distribution Company
CAGR	–	Compound Annual Growth Rate
STM	–	Short Term Market
PX	–	Power Exchange
MCP	–	Market Clearing Price
BU	–	Billion Units
DAM	–	Day ahead market
TAM	–	Term ahead market
DAC	–	Day ahead contingency
RTM	–	Real time market
SCED	–	Security Constrained Economic Dispatch
GDAM	–	Green Day Ahead Market
LDC	–	Longer Duration Contracts
CfD	–	Contract for Differences
RTC	–	Round the Clock
MBED	–	Market Based Economic Despatch

Dr. Rumki Majumdar
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She has worked with eminent economists of Deloitte US, Deutsche Bank, Monetary Policy Committee, India, and the Planning Commission of India in the past and has published several whitepapers with them.

Dr. Rumki Majumdar has done her PhD in economics from the Indian Institute of Science, Bengaluru, India.

Changing Energy Landscape in India and the Emerging Challenges and Opportunities

Supply disruptions in energy and the resulting price rise throw several challenges for India. These include affordability, access, and security. The dynamics of energy demand is also rapidly evolving, with significant changes occurring in both quantum and mix of energy sources. Prioritising the right energy sources, technologies, and best practices will be critical for management of energy demand supply.

The uncertainties associated with the current geopolitical crisis have tempered growth expectations worldwide and made analysts revisit the economic outlook for the world. The IMF recently revised down its growth outlook for the world, including India. The negative consequences of both the pandemic and the Russia-Ukraine war have exaggerated several pre-existing risks that pained the global economy while adding many new challenges.

Higher inflation in the US and Europe, tighter monetary policies in several nations, and disrupted supply chains have concerned investors. These risks have increased the probability of a significant slowdown in the world's three largest economies (US, EU, China) in the near term. One of the biggest drivers of these risks has been the consequence of the disruption of energy and commodities trade that has resulted in persistent inflation despite tighter monetary policies in advanced nations. The other consequence of the energy supply disruption has been Europe's energy crisis conundrum and its vulnerability to its energy suppliers. These are resulting in a complete shift-over in policymakers' vision for the future of energy. These are also likely to have systematic impacts across industries and among the key end-users of the energy industry.

For India, supply disruptions in energy and the resulting price rise throw several challenges. These include affordability, access, and security. India's dependence on crude oil has increased by 10ppt since 2015 to the current level of 87% (June 2022). Demand for crude oil is inelastic and India's rapid growth in economic activity has made it difficult for the energy-importing nation to afford crude oil, whose prices have escalated by more than twice in the past year. Consequent to the rise in crude oil prices, India's import bills have shot up, resulting in a higher current account deficit and higher imported inflation. The RBI's successive rate hikes are likely to increase borrowing costs and slow credit growth. Disruptions to trade and transport have led to challenges in access to crude oil through traditional channels, compelling the nation to look for alternative sources and routes-all of which have not only added to costs of procuring, but also challenges to security and sustenance. A significant dependence on a select few regions for imports of crucial raw materials makes the industry vulnerable to geopolitical tensions in these regions as well as disruptions in these countries' supply chains, which we recently witnessed during the pandemic.

For India, supply disruptions in energy and the resulting price rise throw several challenges. These include affordability, access, and security.

Not to mention, emissions associated with energy usage have been a rising concern. In terms of carbon and greenhouse gas (GHG) emissions, India's situation remains grim by being the third largest global emitter. This is largely attributed to the power sector, which remains dependent on coal for power generation. Particulate matter emissions remain another major concern with over one million premature deaths related to ambient and household air pollution.

The Changing Energy Landscape in India

India's inherent strength has been that of the potential of the pent-up domestic demand. This has provided India immunity to global downturns and tide over uncertainties associated with global exigencies in the past. That said, strong demand and growth have also increased energy consumption and India is strongly dependent on non-renewable sources of energy. Around 80% of India's total energy demand is met by three non-renewable sources—coal, oil, and biomass. Coal has played a pivotal role in India's economic development and its demand has gone up three times from 2000 to 2019. While coal currently meets 44% of the country's primary demand, up from 33% in 2000, it is the predominant resource in the power sector, contributing over 70% of electricity generation in 2019. At the same time, oil demand has more than doubled since 2000 owing to the rise in private and commercial vehicles along with subsidy-led LPG usage in cooking. Since India is a net importer of crude oil, the surge in demand for oil has led to a higher dependence on imports of crude oil, which stood at 75% in 2019.

Several drivers and inhibitors have shaped the contours of India's energy industry landscape (in terms of investment and growth) over the years. The Covid-19 pandemic and the Russia-Ukraine geopolitical crisis brought unprecedented disruptions to the industry; many of the external and internal challenges have been exacerbated at a pace never seen before. With India's concerns on overdependence on imports of conventional fuels and the urgency to accelerate the momentum around sustainability and clean energy transitions, the industry is responding to the changing dynamics of external and internal forces.

Recently India initiated several reforms and programmes to focus on sustainability and carbon emissions.

India has recently pledged to achieve the target of net-zero emissions by 2070. The year 2030 is likely to be the first goalpost year for India's net-zero transition, by which the country has committed to reducing greenhouse gas emissions to less than 45%. The pace of regulations and policies are evolving, which will have a direct impact on the energy sector.

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Not to mention, the industry has witnessed changing trends such as increasing competition, changing consumer and end-user preferences, alterations in import destination choices, rising demand for sustainable and reusable resources, and accelerating technology and innovation. Several of the end-users of the industry are witnessing disruptive changes in terms of technology and consumer preferences that were previously not anticipated.

These may have major consequences across the energy sources. The industry is already witnessing increasing pressure to move on the path towards sustainability and is constantly being forced to review its strategy to remain competitive and succeed. For instance, the share of natural gas and modern renewable sources of energy is expanding. Similarly, the growth of solar photovoltaics has been robust driven by resource potential and aided by timely policy interventions and technology cost reduction measures.

Three Disruptors will be Critical

Going forward, reliable and steady access to crude oil will continue to be critical to overall growth and demand for energy. The industry will have to prepare itself for -

Reliable and steady access to crude oil will continue to be critical to overall growth and demand for energy. The industry will have to prepare itself for energy security, sustainability and digitisation.

- **Energy Insecurity:** India is the third largest crude oil importer in the world in 2021. A significant dependence on a select few regions for imports of crucial raw materials makes the industry vulnerable to geopolitical tensions in these regions as well as disruptions in these countries' supply chains, which we are currently witnessing.

- **Sustainability:** The energy industry is at the core of environmental concerns because of its waste generation into air and water impacting health and safety amongst people and the environment. In fact, the industry is responsible for significant levels of greenhouse gas emissions. Over the years, there has been a rising awareness among consumers globally towards environmental damage and sustainability, which in turn, are influencing their behaviour, preferences, and consumption pattern. Younger generations are demanding a cleaner and greener environment for a better tomorrow. Conscious consumers are willing to pay a premium for environmental-friendly products, and rising discretionary income and education are likely to bolster this trend. Rising demand for sustainability and circular economy, public awareness, the interconnectedness of regions, social media outreach, and influential leaders' vision are likely to compel the industry to adapt to alternative energy sources.

- **Digitisation:** Technology and the digital revolution have implications on costs, productivity and performance, meeting industry standards and regulations, and innovation. India's energy industry cannot afford to remain behind. To keep up with global competition and even stay ahead, the industry, its infrastructure, and its workforce have to adapt to a digital future.

Opportunities for India

India's energy choices will have direct and extensive effects on its people's lives, the energy sector, the flow of technology and investment, and the level of emissions. India will have to make enhanced efforts to cut coal use in power generation and explore alternative fuel options that are affordable, reliable and sustainable, improve the efficiency and carbon intensity of industrial output to lower

India's energy choices will have direct and extensive effects on its people's lives, the energy sector, the flow of technology and investment, and the level of emissions.

emissions. An increase in the penetration of low-carbon technologies will help India cut emissions much further.

India's power consumption is going to rise with increasing population and penetration of electricity to the remotest parts of the nation. India will have to explore alternative renewable sources, and India has made decent progress. Six Indian states source close to 10-30% of their electricity from various renewable sources. This has to increase to reduce dependence on coal. However, that will require significant investment in solar and wind capacity additions. With financial fragility ailing the state-owned distribution companies and the impact of economic uncertainties on power demand will impact the business investment in the sector and the risks to bringing down costs.

In the transport segment, electric vehicles have the potential of replacing vehicles running on conventional energy sources. India offers the world's largest untapped market, especially in the two and three-wheeler segment in the long term. The government's policy initiatives to build the ecosystem and reduced costs of production will increase its adoption.

One of the possibilities could be to expand the use of gas in its energy mix. The government is promoting the use of gases and India has a domestic supply of the same at affordable prices.

Considering the abundance of renewable energy sources (solar, wind, tidal, etc.) in the country, India has the potential to become a net exporter of green hydrogen in the coming years.

It would, however, require significant investment and policy support to incentivise new upstream activity and build the ecosystem to support growth. Considering the abundance of renewable energy sources (solar, wind, tidal, etc.) in the country, India has the potential to become a net exporter of green hydrogen in the coming years. Recognising this, and given the realisation of India's dependence on fuel imports amidst geopolitical uncertainties, the government is incentivising manufacturing green hydrogen to meet the potential demand. The aspiration is to become a global hub of green hydrogen manufacturing and exports, thereby catering to both domestic and international demands for green fuel.

Nonetheless, all these alternative energy options have significant challenges that lie ahead with regard to to the cost of production and conversion efficiency, right policy support measures, infrastructure development, investments by OEMs, complex pricing mechanisms, and competitiveness gaps. Besides, there is a wide variation across Indian states in terms of today's demand, supply, and infrastructure built up for various alternative energy sources.

All these alternative energy options have significant challenges that lie ahead with regard to to the cost of production and conversion efficiency, right policy support measures, infrastructure development, investments by OEMs, complex pricing mechanisms, and competitiveness gaps.

Prioritising the right energy sources, technologies, and best practices will be critical for energy. Transitions, given the limited available resources and lack of energy technology innovation, could be a difficult way forward. India will have to collaborate with global partners and experts to build competencies. Making finances available for investment will be the other critical factor for India to explore alternative energy sources.

Vibhuti Garg
Director-South Asia, Institute for Energy Economics and Financial Analysis

Vibhuti Garg is an energy economist. Her focus is on promoting sustainable development through influencing policy intervention on energy pricing, adoption of new technologies, subsidy reforms, enhancing clean energy access, access to capital and private participation in various areas of the energy sector.

Vibhuti has over 17 years of experience. Her work includes enhancing national and international understanding of India's progress; and helping inform governments and financial institutions globally about the pace and opportunities of reforms in India; accelerating more finance into clean energy solutions so as to achieve decarbonisation of the energy sector and also to help achieve the goals of energy security, self reliant India.

Vibhuti holds a Bachelor of Arts degree in Economics from Hansraj College, Delhi University and a Masters in Economics from Delhi School of Economics.

Prospects and challenges of harnessing renewable sources of energy in India

India needs to transition to renewable energy not just to mitigate the climate risk. The transition will also enable the government to meet its other objectives of energy security, energy self-reliance, job creation, reducing imports of expensive fossil fuels and, thereby, the import bill.

Climate change is now the biggest risk threatening energy and financial markets and vulnerable people and communities by increasing the incidence of extreme weather events.

To mitigate this climate risk, India has set ambitious targets for renewable energy. At the 2021 United Nations Climate Change Conference or COP26, Prime Minister Narendra Modi ratcheted up India's clean energy targets, pledging to cut emissions to net zero by 2070. Further, he committed to increasing non-fossil capacity to 500 gigawatts (GW), meeting 50% of energy requirements from renewable sources, reducing emissions by 1 billion tonnes, and reducing the emissions intensity of the economy by 45% from 2005 levels by 2030.

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This transition becomes even more critical to reduce reliance on expensive fossil fuel risks. The price volatility of oil and gas has exposed the vulnerability of nations relying on such costly fuels. Recently, oil and gas prices have been highly volatile, reaching unprecedented lows in 2020 and record highs in 2021 and 2022.

Strong economic growth in India will lead to a rise in electricity demand, and we already see evidence of this. After a slowing of demand, even before COVID-19, due to a sluggish economy and a further dip during the pandemic, easing lockdown restrictions and restarting industrial activities have revived electricity demand. As a result, all India peak demand crossed ~200 GW in July 2021 for the first time, and, in April 2022, it crossed 207GW.

The renewable energy sector looks promising as the demand is likely to start picking up again, buoyed by increased economic activity due to various measures undertaken by the government.

Transition to renewable energy is now almost synonymous with countries committing to net zero emissions. While it would include demand side measures like energy efficiency, carbon capture storage etc., the larger focus is on the supply side by increasing the deployment of renewable energy.

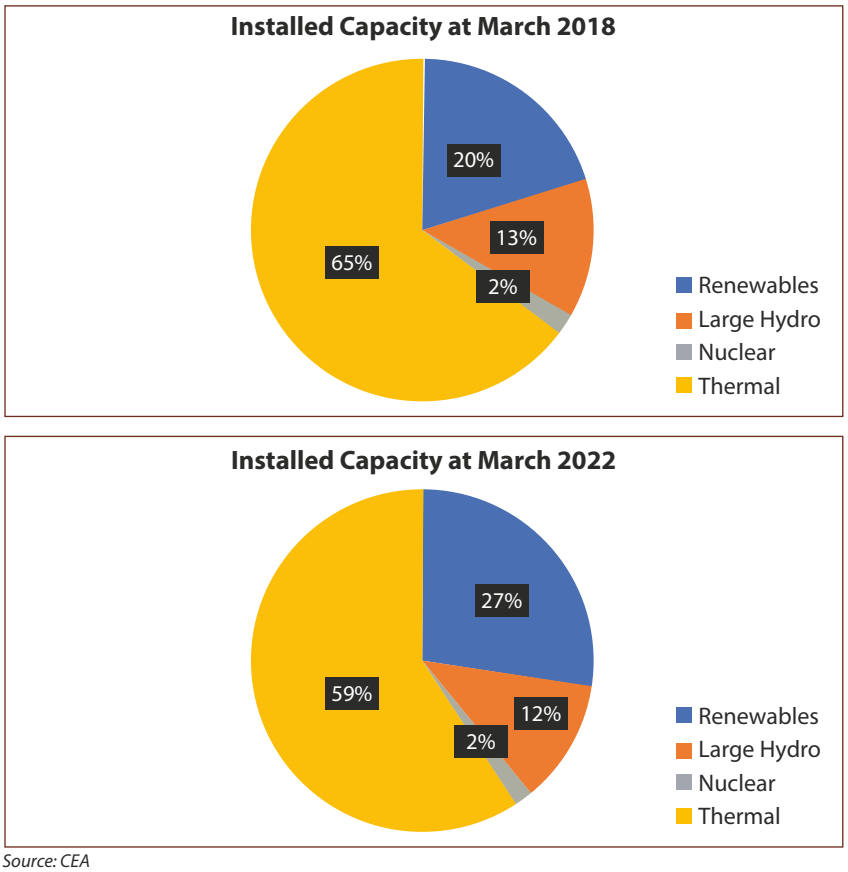
Renewable Energy Landscape in India

A. Current Status

As of March 2022, India has 400GW of installed capacity, which is still dominated by thermal. However, the share of thermal has gone down to 59% in FY2021/22 from 65% in FY2017/18, while the share of renewables has gone up to 27% from 20% during the same period.

Large hydro and nuclear shares have remained constant over the years.

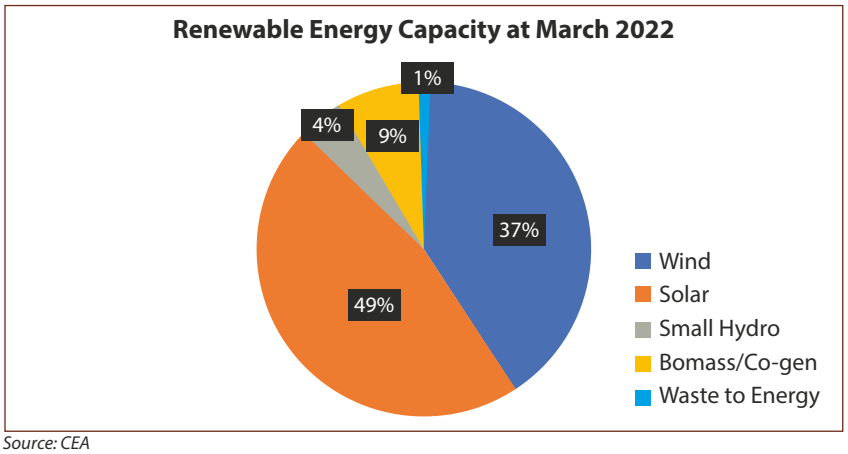
Figure 1: India's Installed Capacity Mix



Source: CEA

Solar dominates the renewable energy capacity with ~50% share, followed by Wind (~37%), Biomass/Cogen (~9%), Small hydro (~4%) and Waste-to-Energy (~1%).

Figure 2: Renewable Energy Capacity at March 2022



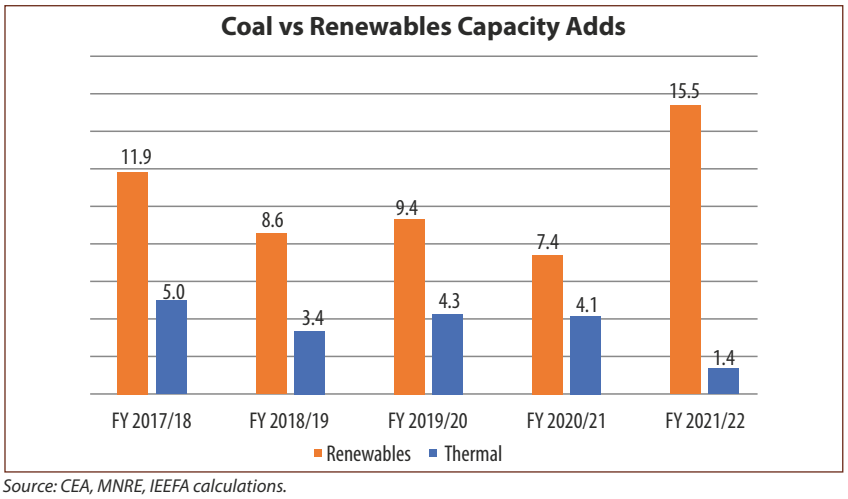
Source: CEA

If we look at generation, 81% of total generation in FY2020/21 is from thermal, with ~74-75% alone from coal. However, in the last 2-3 years, the share of solar and wind generation, although low, has increased rapidly to 11-12%. Furthermore, if we include hydro, then the share of generation of renewable sources increases to 16-17%.

In the last few years, renewable energy capacity addition has outweighed thermal capacity.

In FY2017/18, India saw the addition of 12GW of renewable energy capacity as against 5GW of coal capacity. However, while renewable energy capacity addition has been increasing, the pace slowed down after FY2017/18 until FY2020/21.

Figure 3: Coal vs Renewable Capacity Addition over the years



Source: CEA, MNRE, IEEFA calculations.

A drop in electricity demand due to slower economic growth, and the COVID-19 pandemic choked the expansion of renewable energy capacity. Installations picked up in FY2021/22 with an increase in the pipeline renewable energy auctions continued. India added a record high 15.5GW of renewable energy capacity in FY2021/22, including record solar capacity installations of 13.9GW in a year.

On the other hand, annual coal power capacity additions were ~4-5GW in the last few years, but it hit rock bottom in FY2021/22 with 1.4GW of net new coal capacity. While the total gross new coal capacity commissioned was 4.4GW, the retirement of 1.5GW of end-of-life coal capacity and conversion of 1.5GW of capacity to behind-the-meter captive use meant that net new capacity addition was low.

B. Future Outlook

The International Energy Agency's (IEA) annual World Energy Outlook's central scenario, which reflects policy intentions and announced targets, expects renewable energy to overtake coal as the primary means of producing electricity by 2025. In fact, IEA sees solar becoming the new king of the world's electricity markets, which is very welcoming.

In February 2021, IEA released its India Energy Outlook, wherein the demand growth is estimated at 5.5% per annum. In its Sustainable Development Scenario (SDS) scenario, IEA considers the declining use of thermal capacity and increasing share of renewable energy. According to the IEA, renewable energy's share in total generation will rise from 20% in 2019 to 55% in 2030 and 79% by 2040.

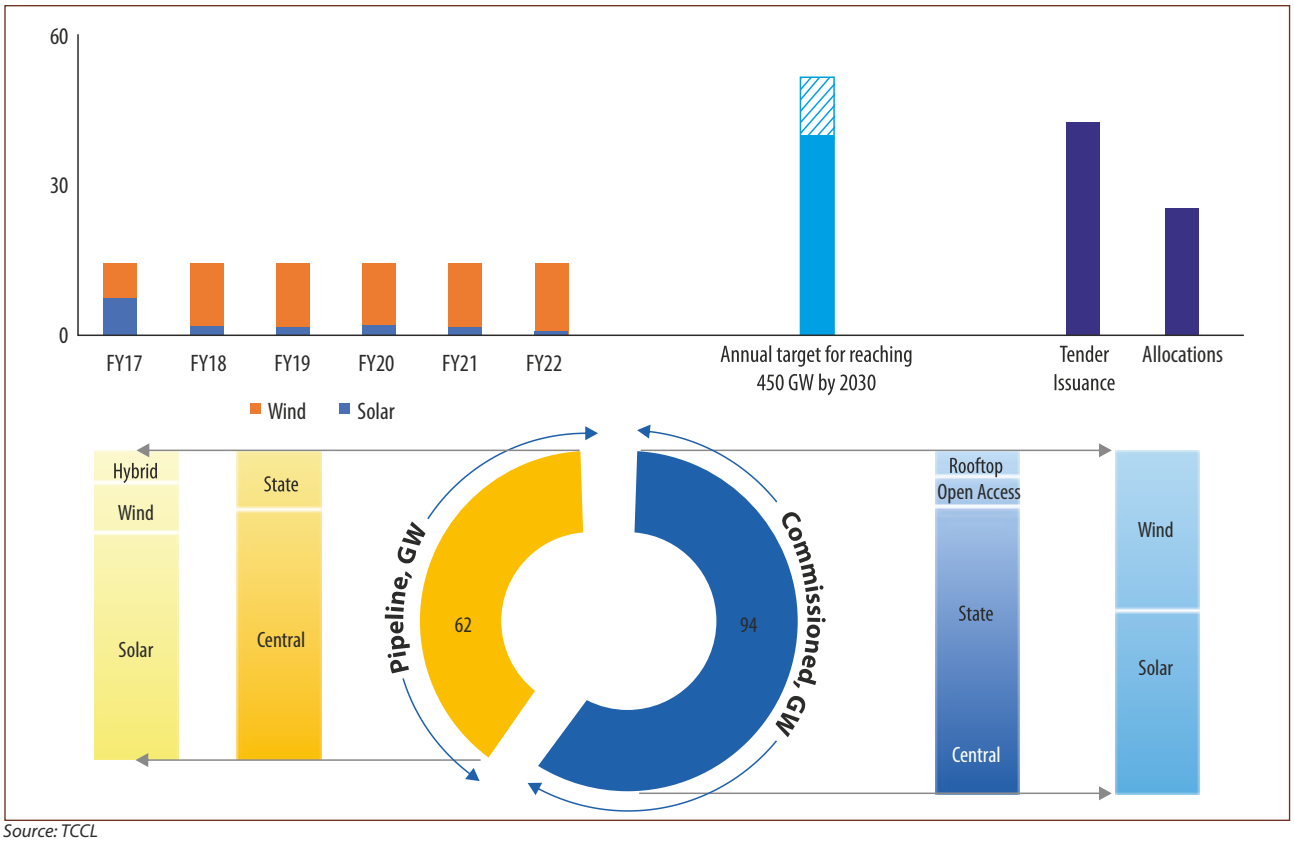
C. Renewable Energy Price Trends

Solar module and battery pack prices have fallen 90% since 2010, whereas onshore wind turbine prices have halved during the last decade. Offshore wind is coming fast, but it may not have cost competitiveness for another decade. The decline in prices has led to the increasing deployment of renewable energy.

Solar tariffs in India over the years have been falling. However, observing the tariff trend over the past six quarters shows that the L1 tariffs discovered in utility-scale solar tenders have increased by an average of 22% above the record-low tariff. Prices have started rising because of an increase in module and freight costs, which is temporary.

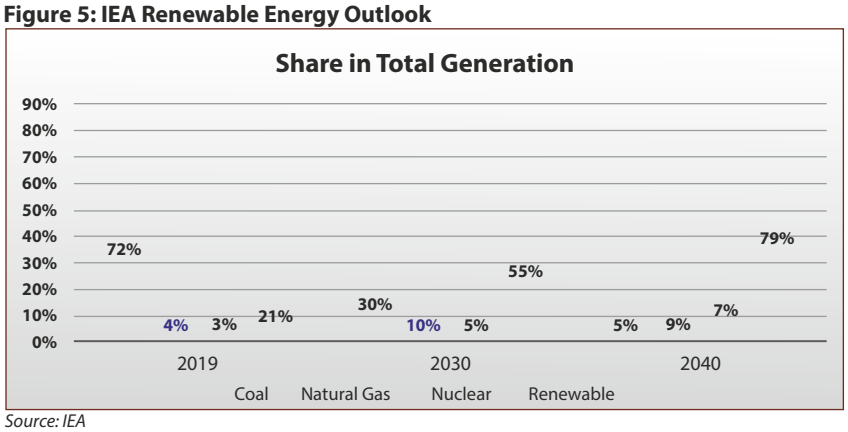
The long-term pricing of solar energy is likely to see a record low of Rs1/Kilowatt-hour (kWh) within the next decade.

Figure 4: Capacity addition and pipeline trend in GW



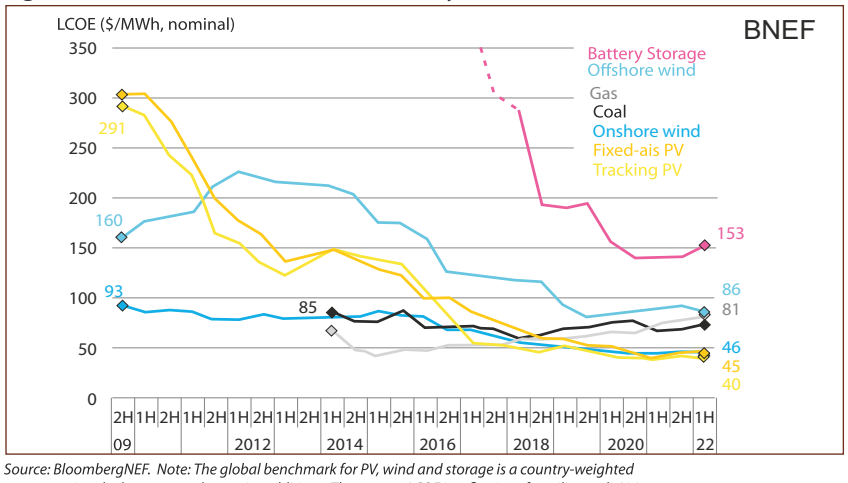
Source: TCCL

Figure 5: IEA Renewable Energy Outlook



Source: IEA

Figure 6: Global levelized cost of electricity benchmarks, 2009-2022



Source: BloombergNEF. Note: The global benchmark for PV, wind and storage is a country-weighted average using the latest annual capacity additions. The storage LCOE is reflective of a utility-scale Li-ion battery storage system with four-hour duration running at a daily cycle and includes charging costs.

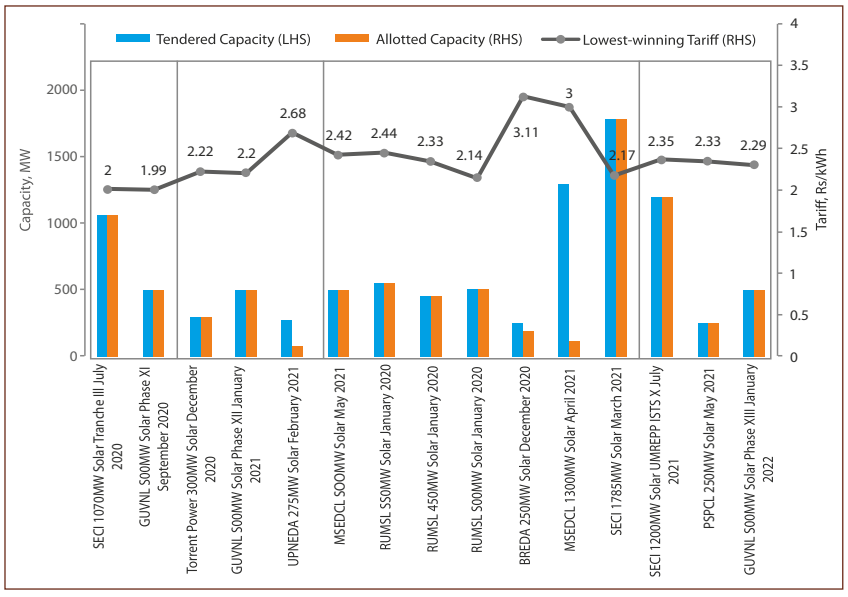
D. Renewable Energy Investment Trends

Investment in renewable energy in India declined by 24% in the FY2020/21, dropping from US$8.4 billion in FY2019/20 to US$6.4 billion in FY2020/21. However, with the revival of energy demand and commitments from various corporates, as well as banks and financial institutions, to exit fossil fuel investments, the share of renewable energy investment is rising.

In FY2021/22, investment in renewable energy totalled US$14.5 billion, an increase of 125% from FY2020/21 and 72% from the pre-pandemic times in FY2019/20.

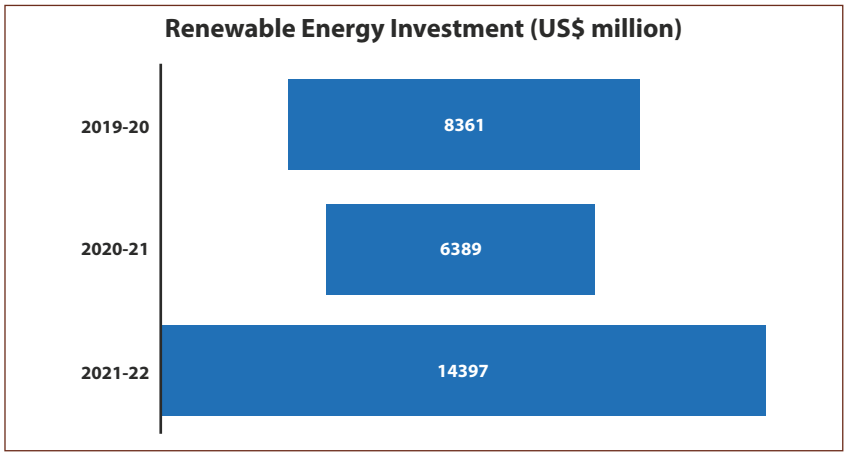
With zero indexation contracts extending for 25-year terms, year one renewable energy tariffs consistently below Rs2.5/kWh are now the lowest cost source of electricity supply in India. The economics of low cost renewable energy has already destroyed the viability of proposed new coal-fired power plants.

Figure 7: Solar tariffs over the last two years



Source: Relevant Tendering Authorities, JMK Research

Figure 8: Renewable Energy Investment in the last three years



Source: IEEFA/JMK Research

According to IEA India Energy Outlook 2021, India would need US$110 billion annual investment for the deployment of renewable energy, battery storage, electric vehicles and network expansion and modernisation of the grid under the SDS. This is approximately three times the current annual investment (US$40 billion) in these sectors. However, to achieve the Net Zero Energy (NZE) roadmap, the corresponding investment requirement will be much higher than the SDS.

Private capital, institutional investors, economic, social and governance (ESG) financing, green bonds, sustainability linked bonds, infrastructure investment funds etc., will play a key role in helping achieve ambitious climate targets.

Measures to Accelerate Renewable Energy in India

While India has made tremendous progress in renewable energy installation, the pace of deployment is slow. To achieve the 2030 target, India needs to add 35-40GW of renewable energy annually.

Policy certainty and continuity, improved health of electricity distribution companies (discoms), market design reforms and access to cheaper finance are the key drivers that will help India achieve its 2030 target.

A. Policy Reforms

Policy inconsistency has been a long standing challenge acting as a roadblock for developers and investors. Varying and ineffective regulations on net metering, open access charges, banking of electricity, imposition of duties and levies, the sanctity of contracts etc., have been significant factors slowing the pace of renewable energy installation.

Private capital, institutional investors, economic, social and governance (ESG) financing, green bonds, sustainability linked bonds, infrastructure investment funds etc., will play a key role in helping achieve ambitious climate targets.

India needs a uniform policy framework that applies to all states for at least the next five years to unlock the full potential of the renewable energy market.

a. Net Metering. A consistent policy and regulatory framework on net metering and banking facilities is needed, which also should apply across India. Unrestricted access to net metering is vital to help the growth of rooftop solar, especially for medium and small scale enterprises.

Policy certainty and continuity, improved health of electricity distribution companies (discoms), market design reforms and access to cheaper finance are the key drivers that will help India achieve its 2030 target.

b. Banking of Power. Restrictions on banking need revocation, at least until the achievement of rooftop and open access state targets. Instead of returning power to the end consumer/developer, discoms could simply pay for the banked energy after each month at their lowest cost of procurement. The respective state regulators should allow discoms to count such procurement of the banked energy towards their Renewable Purchase Obligation (RPO) compliance.

c. **Basic Custom Duty.** The government should postpone the imposition of customs duties on modules and cells to curb a probable price hike in domestic solar modules in the near term. Government should provide support to domestic manufacturing through schemes like Production Linked Incentive (PLI) schemes, rather than imposing trade and non-trade barriers.

d. **Cross Subsidy Surcharge (CSS).** Discoms levy an additional CSS on Commercial and Industrial (C&I) consumers leading to high tariffs. The Draft Electricity (Amendment) Bill, 2020, requires the state electricity regulatory commissions to abide by the National Tariff Policy and reduce the CSS within +- 20% of the average cost of supply. This would strengthen the open access framework for C&I consumers.

e. **Sanctity of Contracts.** Certainty in cash flows is important for developers and investors to build more renewable energy capacity. Honouring contract commitment will instil confidence in the market and help attract requisite capital in the renewable sector. In March 2022, the Andhra Pradesh High Court upheld the sanctity of the contracts and directed Andhra Pradesh discoms to clear all pending dues to generators. To improve the bankability of projects, India must maintain the sanctity of contracts.

B. Market Design Reforms

Market Design reforms can also help in better integration of renewable energy.

a. **Time-of-Day (TOD) Pricing.** Policy support for a time-of-day pricing mechanism incentivises capital investment in vital grid-firming solutions to ensure flexible, reliable peak-time power supply.

India needs more flexible generation sources to maintain grid security and reliability with increasing renewable energy penetration. However, the flexible generation sources are expensive and need the right price signals to become commercially viable. Therefore, time-of-day price discovery is likely to be an important enabling development for better integration of renewable energy.

b. **Deepening of Short-term Market.** New Financial Products will boost national trading of Renewable Energy. In addition, the derivatives market will provide a forward price curve that will help in making investment decisions.

c. **National Pool Real time Market.** India's electricity market should gradually move to a national pool real-time market and optimise generation nationally. This would optimise the huge investment in the national generation fleet and drive the average cost of supply down, forcing the least efficient and most outdated facilities to close and reducing the overcapacity evident in the thermal power sector. Competition based on short-run marginal costs will result in the use of the cheapest electricity possible.

C. Improved Health of Discoms

The Indian electricity sector needs system-wide reforms to improve the financial health of the distribution utilities, which are reeling under huge losses. The Reform Revamped Distribution Sector Scheme (RDSS), with an outlay of Rs 3.03 trillion from FY2021/22 to FY2025/26, is expected to improve the operational efficiency and financial sustainability of discoms. To date, the government has approved over Rs 1.6 trillion under this scheme, segregated under infrastructure upgradation and smart metering heads.

Discoms need to invest in strengthening, modernising, and digitalising their network infrastructure. It is critical that discoms reduce their power purchasing cost and technical and commercial losses by installing smart meters, improving billing and collection, etc., thereby improving electricity supply quality, reliability, and affordability.

Discoms need to transition to the real-time market to meet energy demand, particularly peaking power, to balance low-cost but intermittent renewable energy. As a result, discoms need to improve internal capability further and deploy analytical tools for projection and forecasting to take advantage of market developments and innovations such as Real Time Market (RTM). Additionally, there is a need for capacity building to enable the discoms to use such analytical tools for portfolio optimisation and to accelerate the lowering of aggregate power purchase costs.

D. Access to Cheaper Finance

Access to finance for utility scale and rooftop solar is easier for big and creditworthy developers. However, for small players, credit schemes offered by banks have been typically unattractive.

Government should work on resolving policy and legacy issues to attract the financial institutions to bring in more capital to the deflationary, domestic renewables sector.

With the global appetite changing in favour of cheaper deflationary renewable energy technologies, and with over 200 and more globally significant banks and financial institutions committing to divest their funds from the coal sector, it is time to make India an attractive investment opportunity for renewable energy. In doing so lies the opportunity to build a strong economy with sustainable energy choices.

With the global appetite changing in favour of cheaper deflationary renewable energy technologies, and with over 200 and more globally significant banks and financial institutions committing to divest their funds from the coal sector, it is time to make India an attractive investment opportunity for renewable energy.

Somit Dasgupta
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Somit Dasgupta is a retired officer from the Indian Economic Service of the 1984 batch. He has had a long association with the power sector having worked for more than 22 years in various capacities in the Ministry of Power, the Central Electricity Authority (CEA), the Delhi Electricity Regulatory Commission (DERC) and also the Niti Aayog. He has also served in the Board of the Nuclear Power Corporation of India (NPCIL) and the Bhartiya Nabhikiya Vidyut Nigam Ltd. (BHAVINI). During his stint with the government spanning over three decades, Dr. Dasgupta has also worked in other Ministries/ Departments of the Government of India such as the National Building Organization, Ministry of Urban Development, Ministry of Development of North Eastern Region and the Department of Youth Affairs and Sports. He holds a Ph.D degree from the Jawaharlal Nehru University and the subject of his dissertation was 'Power Sector Reforms in India.' Mr. Dasgupta specialises in areas, such as, electricity laws and regulations, tariff determination, climate change issues, electricity markets and regulatory economics. He is presently engaged as a senior visiting fellow in the Climate Change, Urbanization and Sustainability (CCUS) team at the Indian Council for Research on International Economic Relations (ICRIER).

Electricity markets in India - Mapping their Transition and Transformation

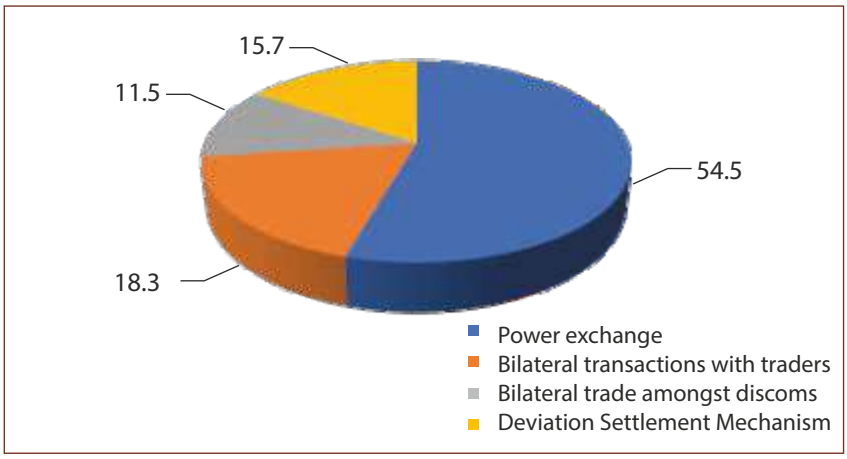
This paper gives a bird's eye-view of the electricity market as it exists in India. I talk about the type of products that are available in our electricity market, physical versus financial derivatives and the role of regulatory bodies, the difference between capacity and energy markets and also what has been the experience of some other countries when it comes to markets.

The Electricity Act 2003 and power trade:

Trading is recognised as a distinct activity in the Electricity Act 2003 (Act). The thrust of the Act is on competition thereby creating a large number of buyers and sellers and trading is one of the platforms envisaged for this purpose. Trading, however, is a regulated activity and requires a license which the electricity regulatory commissions are competent to grant (Section 12). A trader doing inter-state trading needs to approach the Central Electricity Regulatory Commission (CERC) for a license whereas for intra-state trading, the state regulatory commission can grant the license. In addition, the Act also gives the mandate to the regulatory commissions to promote the development of a market (including trading) in power in such a manner as may be specified and shall be guided by the National Electricity Policy (Section 66).

As on date, there are about 25 active traders in the market and separately, there are three power exchanges which are operational. While the Indian Energy Exchange (IEX) and Power Exchange of India Ltd. (PXIL) have been in operation since 2008, Hindustan Power Exchange (HPX) has started its operation in July 2022 itself. The purpose of this paper is to give a bird's eye-view of the electricity market as it exists in India. Diving deep into issues would not be possible given the limitations of space. In this paper, one would be talking about the type of products that are available in our electricity market, physical versus financial derivatives and the role of regulatory bodies, the difference between capacity and energy markets and also what has been the experience of some other countries when it comes to markets. We shall also speak of the latest market reforms currently being debated in the country in the form of Market Based Economic Dispatch (MBED).

Chart 1: Components of short term trade (%)



So, the first thing to see is what comprises of the electricity market? In this paper, we would be limiting to short term markets only which are typically less than one year. Electricity markets in India would include four types of transactions. They are: (1) Distribution companies (discoms) and other bulk consumers buying electricity from traders (2) Discoms buying electricity from one another (3) purchases made in the electricity exchanges and finally, (4) deviation settlement mechanism (DSM). DSM, incidentally, is a regulatory mechanism by which grid stability is achieved by imposing penalty and incentives for over drawl/injection or under drawl/injection from the schedule.

Some Broad Features of the Indian Power Market are:[1]

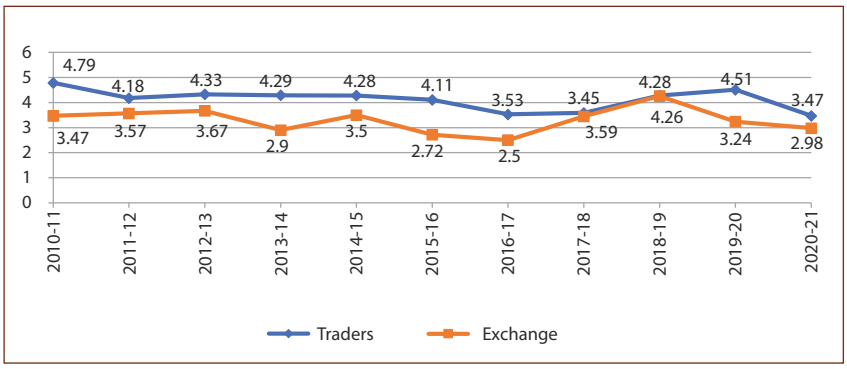
- The short-term market is only about 10.6 percent of the total generation (2020-21), the rest being in the form of long-term power purchase agreements (PPAs). There has hardly been any change in this proportion since way back in 2010-11, the corresponding figure was 9.6 percent.
- The lion's share of short term electricity trade is through the electricity exchange. The share of each component in the short term trade is given in **Chart 1** where one can see the lion's share is through the electricity exchanges (54.5%).
- Though the share of short term trade in total electricity generation is only 10.6% of total generation, the share of electricity exchange only in total generation is only about 5.7%. Bilateral agreements with traders accounts for 1.9%, trade agreements between discoms accounts for 1.2% and finally, for DSM, the figure is 1.6%.
- However, in absolute terms the quantum of short term trade has grown from 81.5 billion units (BUs) in 2010-11 to about 146 BUs in 2020-21. Out of a total of 146 BUs, 79.6 BUs (54%) was handled by the electricity exchanges, 26.6 BUs (18%) through traders, 16.84 BUs

1 All data quoted are from Report on Short Term Power Market in India 2020-21, CERC.

(11.5%) was through agreements between discoms and 22.91 BUs (16%) through DSM.

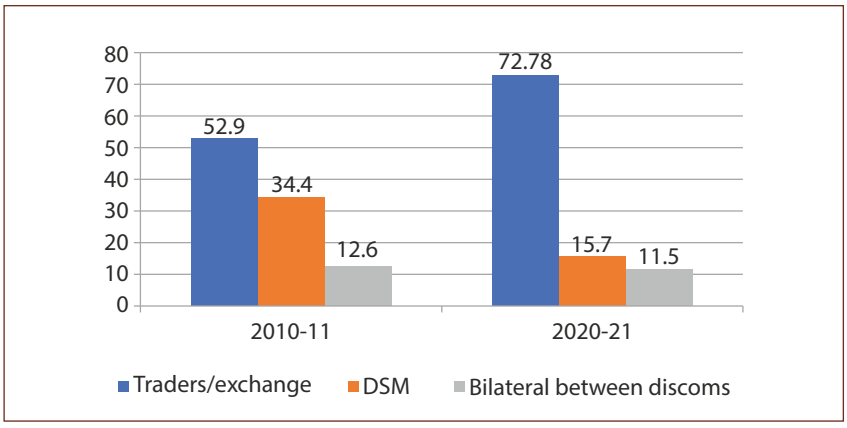
- If we exclude bilateral agreements with traders and also DSM which strictly speaking are not trading activity, the quantum of short term trade falls to 106 BUs (as against 146 Bus).
- The share of IEX in the total transactions handled through electricity exchanges in 2020-21 is 93%. While IEX handled 73.9 BUs, PXIL handled 5.69 BUs.
- While the share of traders was about 18 percent in the total short-term trade, about five traders accounted for about 76 percent share. The Herfindahl Hirschman Index (HHI) is 0.2161 which indicates moderate concentration (CERC).
- The weighted average price of electricity transacted through traders has been higher than the weightage average price of electricity transacted through the exchange (**Chart 2**).

Chart 2: Weighted average price of electricity through traders and exchanges from 2010-11 to 2020-21 (in Rs. per unit)



- The proportion of short term trade through the electricity exchange/traders and DSM has undergone a change over the last 10 years. While the share of the traders/exchange has gone up, the share of DSM has gone down. The share of trade done bilaterally between discoms has remained almost static (**Chart 3**).

Chart 3: Relative share of electricity traded through exchange/traders, DSM and bilaterally between discoms in 2010-11 and 2020-21 (%)



Products Offered

The Indian market has matured over time and a number of products are offered for buyers and sellers to optimise their portfolios. The mainstay, of course, is the Day-ahead (DAM) market but in addition, we have the Term ahead market (TAM) and also the Real time market (RTM). In TAM, bids may be placed which are more than 2 days ahead, whereas, in RTM, trading is almost real-time and delivery takes place after 4 time blocks. Each time block is of 15 minutes duration. There are also other products like the intra-day market, green markets (GTAM) etc. In the DAM, a market determined clearing price is arrived at for every 15 minute block which means that 96 such prices are determined every day. The prices and quantum of electricity to be traded for each product is determined through a double sided closed door auction bidding process. The electricity exchanges also offer their services for trading of renewable energy certificates (RECs) and the energy saving certificates (ESCerts) arising out of the PAT scheme of the Bureau of Energy Efficiency (BEE). **Chart 4** gives the proportion of short term trade each of the products is responsible for, clearly bringing out the supremacy of DAM.

Price Trends in the DAM

Since DAM is the most important market, it would be useful to study the price trends seen in this market ever since the exchanges were set up in 2008. As already mentioned, there are 96 market determined prices in a day. The prices will vary throughout the day, being relatively high in peak hour periods. Prices will also vary if there is a sudden increase in demand or if there is a drop in generation. **Chart 5** gives the average price faced in the DAM market for the period 2008-09 to 2022-23.

Chart 4: Proportion of each product of electricity exchange in 2020-21 (%)

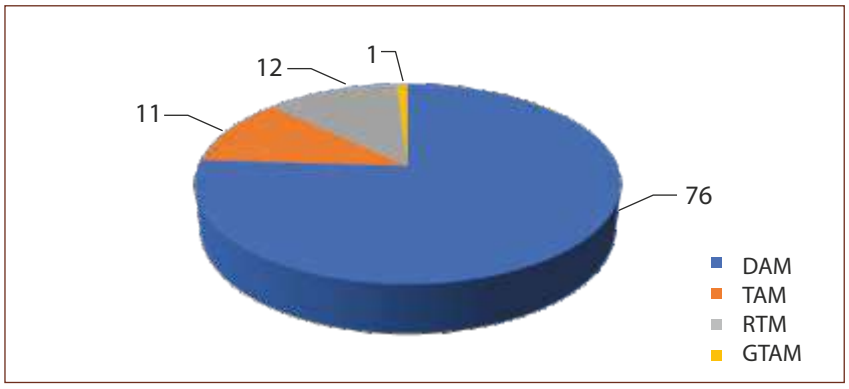
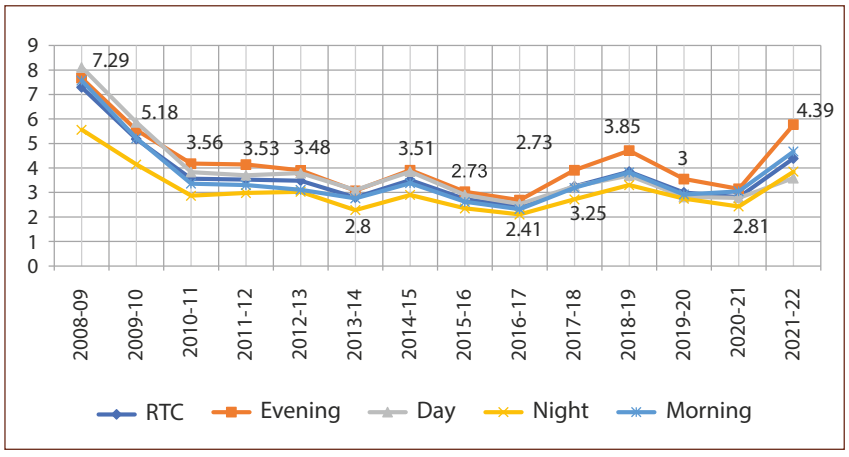


Chart 5: Price trends in the DAM market in Rs./kwh



Note: Only the RTC prices are indicated in the chart.

The DAM price in 2008-09 was quite high at Rs. 7.29 per unit. This was the round the clock (RTC) price which is the overall average. We also have the evening, day, night and morning prices which demonstrate that prices are high during the peak hours. A more granular approach would be to see the prices for each of the 15 minute blocks. Data for the year 2008-09 reveals that while the RTC price was Rs. 7.29 per unit, for some of the blocks, the price had crossed Rs. 10 per unit. This actually let to a large number of coal plants being set up. Banks lent money indiscriminately without bothering to see if the project proposals had coal linkages and/or power purchase agreements. They just felt that the proposals were commercially lucrative given the high price in the DAM market. With the price dropping in the DAM market thereafter, many of the projects ultimately became stressed and the non-performing assets (NPAs) of commercial banks shot up. Prices in the DAM market has also sky rocketed recently with the early onset of summer in 2022 coupled with the Ukraine crisis where price of international coal has gone up manifold. This increased the pressure on domestic coal and a large number of power stations were left with critical stock of coal because domestic supply could not be distributed quickly due to shortage of railway wagons. For some of the time slots, the price shot up to Rs. 20 per unit which led the CERC to introduce a cap of Rs. 12 per unit in early April of 2022. This price cap of Rs. 12 per unit, as of now, is valid till the end of September 2022. Barring these aberrations, the DAM prices have proved to be beneficial to consumers when compared to new coal based plants, especially those situated far away from the coal mines. The drop in DAM prices are because of the fact that far too many coal based plants were in operation and also due to the fact the renewable generation was coming up in a big way. Today renewable generation accounts for almost 10 percent of the entire generation.

The presence of the electricity exchanges proved to be a boon for both generators and consumers. The developers of stranded assets who were without a PPA were able to place their bids in the exchange and recover at least a part of their expenses, allowing them to meet their interest obligations. Similarly, bulk consumers having high-cost PPAs were able to procure cheaper power from the exchange. In fact, availability of cheap power led to a clamour amongst distribution companies to free themselves of all costly PPAs. This move, however, was resisted by the Ministry of Power which turned down the requests because in that case, the affected generators will not recover their fixed costs also.

The presence of the electricity exchanges proved to be a boon for both generators and consumers. The developers of stranded assets who were without a PPA were able to place their bids in the exchange and recover at least a part of their expenses, allowing them to meet their interest obligations. Similarly, bulk consumers having high-cost PPAs were able to procure cheaper power from the exchange.

Physical Versus Financial Derivative Market

Till very recently, the power exchanges were entertaining bids which were less than 11 days away. The reason was that there was disagreement between the

two regulatory authorities, ie. the CERC and SEBI as to which entity was responsible for financial derivatives in the power sector. The matter was litigated before the Bombay High Court which opined that neither of the two regulatory bodies had exclusive jurisdiction to control and regulate forward markets unless suitable changes are made in the regulations concerned. The order of the High Court was challenged in the Supreme Court though in the meantime, the CERC and the SEBI arrived at mutual understanding that CERC will regulate all the physical delivery based forward contracts whereas the financial derivatives would be regulated by the SEBI. The understanding between the CERC and the SEBI was endorsed by the Supreme Court vide its Order of October 2021. The sorting out of this issue will enable the discoms and other large consumers to plan their short term power procurement more efficiently. Simultaneously, the multi-commodity exchange (MCX) can now introduce financial products which will enable discoms and other large consumers to hedge their risks of power procurement. The power markets are expected to deepen the volumes transacted, from 5% of total generation to about 25% by 2024-25.

The multi-commodity exchange (MCX) can now introduce financial products which will enable discoms and other large consumers to hedge their risks of power procurement.

Capacity and Energy Markets

No discussion on markets can be complete without a mention of capacity and energy markets. What is the distinction between the two markets? In capacity markets, electricity producers are compensated for their ability to ensure adequate capacity to meet the demand. Capacity relates more to supply rather than demand. In contrast, in an energy only market, the payment is made to generators to compensate them for the cost incurred purely to generate. The economic rationale behind capacity markets is that generators (including potential generators who may want to enter the market) have to be incentivised to set up new capacity. If it is an energy only market, the price may be so volatile that developers may have no investible resources to set up fresh capacity. This is not to suggest that there are no problems with capacity markets. Existence of capacity markets, at times, leads to building up of excess capacity which ultimately has to be paid by the consumers. Most of the systems in the U.S. have the option for both capacity and energy markets, the only exception being Texas. In the UK, there have been different regimes wherein in one of the regimes, the capacity market was done away with (details given in the next section).

As far as India is concerned, we follow the two-part tariff principle, a fixed part and an energy part. The fixed part consists of return on equity, interest on loan, interest on working capital, operation and maintenance and finally, depreciation. The fixed part basically constitutes the capacity payment and is contingent upon how much of capacity a generator commits upfront. The energy payment accounts for primarily for the fuel input, for example, the price of coal in a coal based station.

British Wholesale Markets and Capacity Payments

Prior to the restructuring of the British electricity sector in 1989, the distribution utilities were vertically integrated bodies. The Electricity Act 1989 overhauled the sector in many ways, such as, restructuring the 74 odd generation utilities into two mainly utilities called the, National Power (40 GW) and Power Gen (30 GW), separation of distribution and retail, introduction of competition in retail etc. What we are going to discuss here, however, is the creation of wholesale market for power, called the Pool. Under this system, the generators had to place their bids in the day-ahead market which were stacked up beginning from the cheapest generator. This was matched against the demand for power as estimated by the grid operator to determine the market clearing price. It was thus a central dispatch system where all generators who bid lower than the market clearing price were asked to dispatch. The point to note here is that the price earned by the generator was inclusive of capacity charges. Since the market clearing price tended to be volatile, in order to bring in some certainty, the distribution companies also made bilateral agreements with generators called contract for differences (CfD). If the market determined price was more than the bilaterally agreed price, the generator would compensate the retailer and vice-versa.

There were some inherent problems with the Pool, mainly because of the duopoly enjoyed by the two generation companies which actually saw the Pool price rising 40% during the first four years of operation. The generators were involved in gaming which led to high capacity payments. The government decided to replace the Pool with the New Electricity Trading Arrangements (NETA) in March 2001. Under NETA, the Pool system was dispensed with buyers and sellers signing long term contracts which included forwards market and spot market. Two electricity exchanges started operating in the UK. The role of the grid operator was reduced to balancing the grid through ancillary services. One notable feature of NETA was that capacity payments were discontinued. Though NETA reduced electricity tariff, it failed to attract investments due to limited profits, leading to a drop in system back-up reserves. By 2006, the reserve power generation capacity dropped from 35% to 22%.[2]

In order to bring additional capacity, further electricity reforms were introduced in 2010. This had many components especially to promote renewable generation, but the point to note is that capacity markets were reintroduced. Capacity market participants had to bid for contracts in auctions which were held four years prior to the delivery date.

2 Liu, J., Wang, J., & Cardinal, J. (2022). Evolution and reform of UK electricity market. Renewable and Sustainable Energy Reviews (161).

Market Based Eeconomic Dispatch (MBED)

A few words on the MBED, a concept floated by the CERC in 2018, needs to be mentioned to complete the discussion on markets. In India, PPAs operate in silos which means that each PPA has an identified number of beneficiaries. This leads to a situation where more expensive plants are getting dispatched and the cheaper ones are remaining idle since there was no demand from their beneficiaries. MBED envisages that all generators and bulk consumers will bid into a day-ahead market and only the relatively economical plants will get dispatched, beginning from the cheapest. The generators will continue to earn a variable charge as they were doing before and if the market clearing price is more than the variable charge that they were earning, they will have to compensate the bulk consumer and vice-versa. This is something similar to the concept of CfD, enunciated earlier. The generators will also be entitled to their fixed charge as determined earlier and this payment would be made outside the market. Modelling exercises reveal that if all generators participate in the MBED, there would be a saving of about Rs. 12,000 crore per year. However, before this concept can be set into motion, changes have to be in several regulations apart from infrastructure and systems.

To conclude, the purpose of this article was only to introduce the subject of power markets and to give a bird's eye-view to the reader. This subject is complex and needs extensive study to unravel its full repercussions.

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Dr. Sonal Gupta is an accomplished energy professional and a passionate educationist with multifaceted work experience in the industry, academia, and research. She is a result-oriented decisive leader, a change agent, with proven success in conceptualizing ideas and strategic planning. Her areas of research writing and presentations revolve around the energy value chain, risk management, climate change, renewable energy, economics, and trading.

Green Day- ahead market (G-DAM) in India: Need and opportunities

The idea behind implementing G-DAM was to give current renewable energy projects with existing Power Purchase Agreements (PPAs) or surplus electricity more ways to utilize their generation as well as augment the renewable capacity addition toward India's vision as a sustainable and efficient energy economy. This would also bring back investors' confidence and would increase investment in Renewable Energy generation.

1. Introduction

India is one of the countries most susceptible to climate change due to its extreme temperatures and rainfall deficit. This has a huge impact on its agricultural market. In 2015, the power sector was the largest contributor of CO2 emissions in India, contributing about 50% (1066 Mt) of the 2066 Mt of total CO2 emissions from fuel combustion. This has led the Government of India (GOI), under the Paris Agreement, 2015, to take initiatives at producing clean energy: to achieve 175 GW of renewable capacity (100 GW of solar, 60 GW of wind, 10 GW of biomass, and 5 GW of small hydro) by 2022 with 50% renewable energy in India's energy mix by 2030. Currently, the renewable installed capacity is around 28% of the total installed capacity of power stations in India, despite its huge potential. Hence, this calls for the Government's intervention to introduce green markets to accelerate the flow of green energy.

The intention to incorporate renewable energy has been observed in the Electricity Act 2003, wherein the Act stated that the State Electricity Regulatory Commissions (SERCs) should promote the grid connectivity of electricity generated from renewable sources through tariff regulations and specify a minimum purchase obligation for renewable power by the state distribution companies. In the year 2006, the National Tariff Policy specified that the distribution companies should buy renewable energy-based electricity at certain preferential feed-in tariffs (FIT) as determined by the SERCs along with guidelines mentioned for the SERC to set minimum renewable purchase obligations (RPOs) at the state level. Electricity is a concurrent subject in India and is regulated by both the Central and State governments. To put the Act into action, the GOI has been introducing various green energy products at the two trading platforms since the year 2011, thereby increasing the participation of stakeholders' of Renewable Energy (RE) in the market.

2. The Platform for Renewable Energy Trading

An electricity market is a place where buyers and sellers come together for the purchase and sale of electricity. It can be a physical market or a virtual one. In a virtual market, bidding and negotiation take place online followed by the successful participants entering into a transaction. In India, there are two platforms for renewable energy trading-

1) **Power Exchanges:** A power exchange is a virtual market platform wherein the buyers and sellers trade electronically. Currently, there are three operational power exchanges in India: namely Indian Energy Exchange Limited (IEX), Power Exchange India Limited (PXIL), and Hindustan Power Exchange Limited (HPX). The first two were established in the year 2008 and the last been set up recently in July 2022. In India, power exchanges hold collective transactions. The benefit of trading through exchanges involves no counterparty risk, lesser liquidity risk, and transparency in operations.

2) **Over the Counter (OTC) Market:** In the OTC market, bilateral transactions take place between the buyers and sellers, who can either transact directly or may transact through an electricity trader. Here, the price and volume of electricity are mutually decided through negotiations or a competitive bidding process. Any inherent risk in these contracts is borne either by the parties or by the trader, depending on the terms and conditions of the contract. These contracts can be customized according to the requirement of the participants.

3. Renewable Energy Products

Renewable energy is an unpredictable commodity, which can be traded and delivered but cannot be stored. It is used to meet the energy deficit of one area with the energy surplus of another region. In India, long-term power purchase contracts (7 years and above) are prevalent, hence to meet the short-term needs, power exchange play a vital role. Exchanges ensure fair, neutral, robust, and efficient price discovery for different products. For the price discovery, they follow 'Double-sided closed bidding auction', 'Continuous trade', and 'Open auction '. Moreover, they provide rapid and widespread price dissemination through data sheets and aggregate demand & supply curves. They may operate round the clock and offer standardized contracts based on the physical delivery of renewable electricity. The products traded at a power exchange include the following:

1) **Renewable Energy Certificates:** In a country like India, which has a huge renewable energy potential and a large number of renewable energy generators, the scope of renewable energy trading is immense. The Government's mandate on bulk purchasers like Discoms, open access consumers and captive users to buy a certain

One REC is issued when one-megawatt hour of electricity is generated from a certified renewable energy source.

percentage of electricity from renewable energy sources like solar, wind, biomass, small hydro, municipal solid waste, etc. under Renewable Purchase Obligations (RPO), have led to an introduction of REC (Renewable energy certificates) in India from 2010-11. Monitored by the Central and State electricity regulatory commissions (CERC and SERCs), the goal was to encourage competition and create a market for renewable power across states through centralized monthly REC trading. The RECs traded on the two power exchanges, Power Exchange of India Limited (PXIL) and India Energy Exchange (IEX) are a way to incentivize RE generation in India through no trading margin. The RECs' price is based on the demand and supply of the market players with prices lying between the forbearance price (maximum price) and floor price (minimum price). The Central Electricity Regulatory Commission (CERC) specifies these prices. The penalty is supposed to be paid by the defaulters under the Electricity Act, 2003. One REC is issued when the one-megawatt hour of electricity is generated from a certified renewable energy source. RECs are traded in two forms i.e. Solar and Non-Solar. Initially, the launch of REC led to an increase in the share of renewable energy in the electricity mix. The power market participants, such as generators, traders, and distribution companies were able to cut costs more effectively along with meeting their RPO targets. However, ten years down the line, its trading was suspended in July 2020 by the Appellate Tribunal for Electricity, when an appeal was made to abolish the price floor for RECs. Nevertheless, The Ministry of Power is planning to reestablish it to meet its renewable energy target for 2030 under the Paris Agreement.

2) **Green Term-Ahead Market:** The Green Term-Ahead market (G-TAM) was launched by IEX on 21st August 2020, with an aim same as that of REC but providing flexibility and spatial granularity to the renewable energy market stakeholders to trade through a variety of products according to their needs. In the absence of trading platforms, the problem of 'curtailment' is a cause of worry for renewable energy-rich states like Karnataka, Tamil Nadu, and Andhra Pradesh causing huge losses to these firms. With G-TAM, the RE generators can trade surplus renewable energy on the electricity market without worrying about reserving their capacity or entering into a long-term power purchase agreement (PPA) in advance with generators or Discoms. The feed-in tariff system has given way to a competitive bidding mechanism for renewable energy pricing, allowing competition on power exchanges, which promotes improved price discovery and increased trading volume.

   Since the REC mechanism has been abolished in 2021, G-TAM allows RE generators to develop new modes to sell electricity outside the traditional PPA and REC frameworks fostering the growth of renewable energy in the nation. G-TAM constitutes of four types of short-term contracts (Solar and Non-solar), as described below:

   a) ***Intra–day Contracts:*** This is a 15-minute national contract available for trading throughout the day, with a cut-off 3.5 hours before delivery.

   b) ***Day – ahead Contingency Contracts:*** A 15-minute national contract available for trading days for the next day from 0000 to 2400 hrs. However, the trading session is from 1500 to 2300 hrs, each day.

   c) ***Daily Contracts:*** These are available for trading on each trading day for delivery of electricity on T+2 (T = trading day) day onwards. The contracts cover 15 minutes or a combination thereof from 0000 hrs. to 2400 hrs. of a day. The seller may revise the schedule by 0700 hours on D-1 (D = delivery day) with a deviation of up to 15 percent.

   d) ***Weekly Contracts:*** These are available for trading every Friday and Saturday for delivery of electricity in the upcoming week from Monday to Sunday. The seller profiles are aggregated in MWh terms. The seller may revise the schedule by 0700 hours on D-1 with a deviation of up to 15 percent.

   Due to the rising renewable energy consumption in India by the open-access consumers and Discoms, there has been a boost in liquidity in the G-TAM which will further lead to an increase in the merchant RE capacity additions in India.

3) **Green Day-ahead Market:** The Green Day Ahead Market (G-DAM) was launched on October 26, 2021. It enables two-sided, anonymous, closed-crowd renewable energy auctions the following day for the electricity produced through Solar, Non-Solar, and Hydro energy. India is the only electricity market in the world to have implemented a Green Day Ahead Market (G-DAM) exclusively for renewable energy. The exchange invites bids for conventional and renewable energy in an integrated manner through separate bid windows. Compensation occurs sequentially, first in the renewable segment, which has mandatory execution status considering the availability of transmission corridor, followed

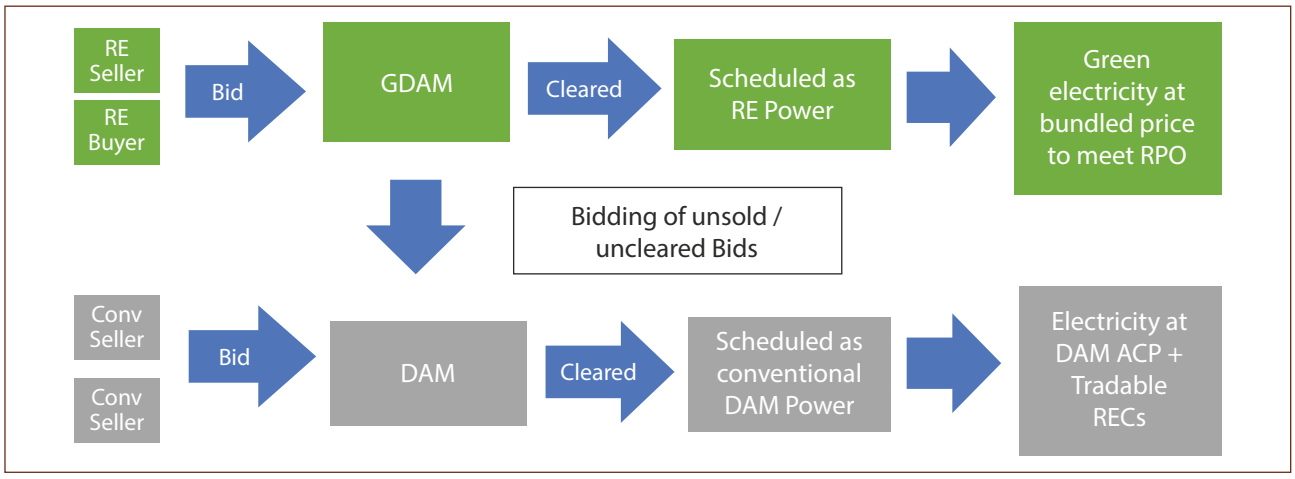

Fig 1. G- DAM Trading process

G-DAM enables two-sided, anonymous, closed-crowd renewable energy auctions the following day for the electricity produced through Solar, NonSolar, and Hydro energy. India is the only electricity market in the world to have implemented a Green Day Ahead Market (G-DAM) exclusively for renewable energy.

by the conventional segment. The bidders have the option to bid for rene¬wable and conventional power separately and can carry forward un-cleared bids from the green market into the conventional market at a premium – or discount, according to their requirements i.e. the participants can clear their uncleared volume in the Real-Time market and DAM as well. As of March 31, 2022, a total trade of 920.4 MUs has been conducted, with an average daily buy of 21.6 MUs and an average daily sell of 11.6 MUs, with the average market clearing price of Rs 5.29 per kWh. This has created a new opportunity for renewable energy generators.

4. Trading Process for G-DAM

The trading process of G-DAM and DAM goes in tandem with the preference given to bids under G-DAM. The Integrated bidding session for Green Day Ahead Contract and Day Ahead Contract starts at 10.00 am until 12.00 pm on all seven (7) days of a week (See Fig.1). The Members may choose to shift the unsuccessful bids of Green Day Ahead Contract to Day Ahead Contract with same or different price through 'Order Carry forward (OCF).

The provisional bid matching process for each contract with the Green Day Ahead contract takes place first, followed by the matching of bids under the Day Ahead contract, taking into account the unsettled bids of the Green Day Ahead contract. The provisional market settlement price or the unconstrained MCP is determined separately for the Green Day Ahead contract and the day-ahead contract based on the unconstrained scenario.

Information regarding the provisional market settlement price is then sent to all members by 12:20 PM. All buyers are required to maintain available funds in their respective settlement accounts as per the provisional obligation report. Based on it, the exchange submits a combined request for verification and reservation of the transmission corridor to the NLDC (National Load Despatch Centre) by 1:00 PM, which is required for the successful Green Day Ahead contract and the Day Ahead contract. By 2:00 PM NLDC confirms the available transmission corridor for scheduling and the Exchange verifies the available funds in the Settlement Accounts of all provisionally selected Exchange Members. Those Members who have not brought sufficient funds shall be excluded from the final bid matching process. The final Bid matching takes place based on the final clearing price and volume, and the availability of the transmission corridor report received from the NLDC. By 2:45 PM, the exchange issues the final obligation to the members, and by 3:00 PM the exchange files the application for scheduling of G-DAM and DAM to the NLDC.

In the event of congestion in the transmission corridors, the method of market splitting is adopted by the Exchange, which may result in different prices for different areas. An additional congestion amount is transferred to the congestion revenue account, which is the

The creation of the daily green power market has aided in the deepening of the green power market and the provision of competitive price signals, as well as the capacity to trade green energy in the most transparent, flexible, competitive, and efficient manner. This would lead to a gradual shift from Long term PPA to short-term transactions paving the way to a sustainable future.

difference between the total funds payin and total funds payout, arising due to market splitting. The transfer of funds shall be as per the provisions of the CERC (Power Market) Regulations, 2021, as amended from time to time.

Finally, by 5:30 PM, NLDC communicates acceptance of scheduling of G-DAM and DAM. For compliance with Renewable Purchase Obligation (RPO) and Hydro Purchase Obligation (HPO), the Exchange is supposed to provide a detailed statement consisting of the total quantity of renewable energy (solar/ non-solar/ hydro energy) which has been purchased by the successful buyer in Green Day Ahead Contract (GDAC). According to the procedure laid down by the CERC, any shortage or excess delivery of electricity from the total schedule is settled through the Deviation Settlement mechanism.

A Way Forward

India is battling against the pressing issue of climate change. G-DAM has been launched at a time when the country is facing a shortage of coal and there is an urgent need to reduce its dependence on the imported source of fossil fuels.

The idea behind implementing G-DAM was to give current renewable energy projects with existing Power Purchase Agreements (PPAs) or surplus electricity more ways to utilize their generation as well as augment the renewable capacity addition toward India's vision as a sustainable and efficient energy economy. This would also bring back investors' confidence and would increase investment in Renewable Energy generation.

Before the launch of G-DAM, renewable energy was traded through G-TAM, which required a firm to wait an additional week to bid again if it did not purchase the electricity through a tender procedure. G-DAM, on the other hand, lets a corporation engage in daily auctions, giving it more freedom to acquire energy at competitive prices. The creation of the daily green power market has aided in the deepening of the green power market and the provision of competitive price signals, as well as the capacity to trade green energy in the most transparent, flexible, competitive, and efficient manner. This would lead to a gradual shift from Long term PPA to short-term transactions paving the way to a sustainable future.

Although the G-DAM framework may take some time before it is fully embraced by all participants due to its multiple pricing and unconventional market structure, it holds a promising future ahead.

Even as the country's renewable energy penetration is increasing by the day, renewable energy's participation in the existing Day Ahead Market and Term Ahead Market segments has remained low (less than 1%), because the system does not differentiate between conventional and green power, and the realization going to the generator is at par with conventional power. With the introduction of G-DAM, this issue has been resolved too.

Trading of GDAM in tandem with DAM has led to better grid management and lesser uncleared volumes, leading to reduced losses, which were otherwise high due to the denial of State Government owned utilities to purchase power from the renewable energy generators citing some issues regarding grid management.

Although the G-DAM framework may take some time before it is fully embraced by all participants due to its multiple pricing and unconventional market structure, it holds a promising future ahead.

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Dr. Alok Pandey is the Dean- School of Management at GD Goenka University, Haryana. With over 25 years of experience, he has taught as full time senior faculty at Institute of Management Technology (IMT)-Ghaziabad, National Institute of Financial Management (NIFM)-Faridabad and at Lal Bahadur Shastri Institute of Management (LBSIM)-Delhi. In addition he has taught full term courses as visiting faculty at several premier business schools. As an administrator he has served as Director- Advance Studies at Institute of Cost Accountants of India (earlier ICWAI) and as Director at Institute of Management Studies-Ghaziabad. He has held board level positions and is expert in the area of Derivatives, Investments, and Corporate Finance. With a strong interest in sustainability, he has several publications to his credit. His books have been published by Pearson Education, McGraw Hill, Macmillan India and his research articles have appeared in ABDC listed journals.

Challenges and Opportunities in Popularizing Electric Vehicles in India

What is the future of EVs in India? How do we ensure that they are accepted by consumers using vehicles with internal combustion engines as a sustainable alternative? EVs in India present an exceptional opportunity for fueling economic growth in a sustainable manner. They are a long term economically viable solution and sustainable solution for mobility.

Electric vehicle (EV) sales has seen a phenomenal increase around the world and several countries have announced their plans to end sales of vehicles based on their internal combustion engines in the near future. European countries, such as Norway, would be achieving the goal by 2025 whereas France and the United Kingdom would like to do the same by the year 2040. The year 2022 witnessed exponential growth in manufacturing and sales of EVs, with China-based EV manufacturers emerging as the market leader[1]. They are closely followed by the manufacturers in the Europe and the USA. China shipped over 1.14million units of passenger EVs in first quarter of 2022 up from a meagre 0.5million in the first quarter of 2021. This was a whopping year-on-year increase of 126%. Internationally, EV shipments grew 79% YoY in Q1 2022 to reach 1.95 million units. Of these, battery electric vehicles (BEVs) accounted for 73% and plug-in hybrid electric vehicles (PHEVs) for the rest[2]. Most global EV manufacturers are using cutting edge research and development to improve battery performance, in vehicle entertainment, and advanced driver assistance systems to provide higher value to the customers.

Manufacturers such as Tesla, BYD Auto, Wuling, Volkswagen and BMW have registered phenomenal growth in last few years. Tesla's shipments grew 68% YoY in Q1 2022 and are expected to cross 1.3 million units by the end of 2022, BYD Auto emerged as China's top EV seller during Q1 2022 with its EV shipments growing by 433% YoY to reach more than 0.28 million units. The company is now focusing on manufacturing BEVs and PHEVs and completely withdrawing from internal combustion engine business. In Q1 2022, BYD's BEV and PHEV shipments grew 271% YoY and 857% YoY, respectively. Similarly, the Wuling Hongguang Mini EV, manufactured by Wuling Motors, the joint venture between Chinese state owned automobile manufacturer SAIC and General Motors, is now the most sold EV model in China. Wuling now holds the third rank in the global EV market. The European automakers BMW, Volkswagen, Jaguar Land Rover and Volvo are giving a tough competition to China-based manufacturers of BEV and PHEV. Volkswagen with its ID models intends to compete head on with Tesla to capture a significant share of the EV segment. During Q1, Volkswagen's EV shipments increased by 25% YoY. China remains Volkswagen's top EV market, followed by Europe and North America. Across all major regions, the company's all-electric ID.4 model registered most shipments. BMW on the other hand has however adopted a slightly different strategy. Its focus is on PHEV segment rather than on BEV. BMW's 16% YoY growth is mostly due to its offering of several new and improved PHEV models. BMW's BEV shipments are predominantly driven by the company's i-series models, while BMW Series 3 and Series 5 models are driving its PHEV shipments.

Most global EV manufacturers are using cutting edge research and development to improve battery performance, in vehicle entertainment, and advanced driver assistance systems to provide higher value to the customers.

Indian automakers are not far behind. One of the largest Indian automakers, Mahindra & Mahindra, recently announced its foray into electric vehicle manufacturing in a big way. The company has come since its acquisition of Bengaluru-based EV brand Reva Electric Mobility back in 2010. The company produced a small 4-seater electric vehicle named Reva. The new vehicles will come with Mahindra's new design philosophy and would be based on INGLO EV platform, a common modular electric skateboard. The components for this electric skateboard platform will be sourced from Volkswagen's MEB architecture which is scalable and designed for a variety of wheelbases. It would be launching four models between 2024 and 2026 and has a plan to invest over USD 1 billion in electric four wheeler vehicle manufacturing business, over $250million of which has been raised from British International Investment, the UK's Development Finance Institution.

Another Indian automaker, Tata Motors, has already made its foray into the EV market and its vehicles, especially the Nexon EV and Tigor EV, are witnessing strong consumer interest in India. Overall, the EV sales (390,399) in first half of 2022 surpassed the sale of EVs in the entire year of 2021 (311,420). In all 240,622 electronic two wheelers were sold in first half of 2022, a 656% YoY growth compared to 31,823 units sold during the same period last year.

Challenges for Adoption of EVs in India

Evs in India have seen a growth (CAGR) of 205% and 149% domestic sales volumes in two-wheelers and four-wheelers respectively during FY20-FY22 and the future looks promising[3]. This growth is however on a very low base, and in reality, vehicles with internal combustion engines or with hybrid engines, are still much more popular than EVs in India. The popularity of EVs in India is being hindered due to several reasons. Primarily there are four major

1 "World's electric vehicle fleet set to cross 20 million as adoption increases globally". Bloomberg. 8 April 2022. Retrieved 18-08-2022.
2 "Exclusive: Tesla plans new Shanghai plant to more than double China capacity - sources". Reuters. 24 February 2022. Retrieved 18-08-2022.
3 "Domestic sales trends". siamindia.com. Retrieved on 18-08-2022.

Table : EV Sales in India 2022

	VEHICLE TYPE		
Month (2022)	**4 - wheeler EVs (LMVs)**	**2 - wheeler Evs**	**All Evs**
January	204	27,590	48,166
February	144	32,458	54,053
March	66	49,643	77,250
April	450	49,189	72,588
May	678	39,520	65,879
June	272	42,262	72,463
Total	1,841	240,662	390,399

Source: Ministry of Road Transport and Highways, Govt. of India

challenges which have hindered the sales of EVs in India, and these are:

(i) Higher Price of EVs: Both two and four wheelers EVs are exorbitantly priced as compared to vehicles with internal combustion engines. Despite hefty subsidies support by the Government, most two wheelers with range above 50 Kms per charge, cost above Rs. one lakh and four wheelers above 12.0 lakhs. The four wheelers EVs manufactured by Tata Motors and Mahindra & Mahindra have a range between 100 to 300 Kms per charge. The comparative vehicles with internal combustion engines are cheaper by Rs 5-6 lakhs approximately. Similarly, the two wheeler EVs are costlier by over 30%. The operating cost advantage to the consumer, buying these vehicles, is often offset by the higher purchase price and thus keeping them away from the vehicles.

(ii) Low Range of Batteries: Most two wheeler EVs have a range of 40 to 60 Km and 4 wheelers EVs between 120Km to 300 Km on single charge. In comparison, on a full tank of petrol a car with internal combustion engine may have a range of a thousand kilometers and can be refueled quickly. Most consumers who buy an EV, wish to have a similar ownership experience from EVs. The positivity of experience depends on power, range and is aided by time for refueling or recharging. The refueling can be done in minutes, whereas the fastest charging EV would need 15 to 45 minutes to be capable of driving a reasonable distance[4]. A full conventional charge needs around seven hours. The charging time depends on the energy density of the battery which is turn depends on the type and technology used in manufacturing them. Globally DC fast chargers can give a range of 150 to 300 Kms of range in 30 minutes of charging. With improvements in battery technology, new electric vehicles may have a higher range and shorter recharging time, but they come with a high premium currently, leading to low acceptance level by the consumers in India.

The Government of India in its recent annual budget has announced that it will bring a battery swapping policy to boost use of EVs in the country. This is an important step in view of space constraints for setting up charging stations. The standardization and interoperability standards will be formulated as part of the policy. It is worth noting that absence of publicly available charging stations and battery swapping services have inhibited the consumer from buying the EVs in India.

(iii) Poor Battery Charging Infrastructure and Lack of Battery Swapping Services: The battery charging infrastructure for a country with size and population like India's, is still in infancy. There are close to 2500 charging stations, of which in close to 1600 are in nine mega cities with populations of over 4 million. These are: Delhi, Mumbai, Kolkata, Chennai, Bengaluru, Hyderabad, Pune, Ahmedabad and Surat. This is woefully inadequate considering the numbers of vehicles being sold each year. Battery swapping has been initiated by some vehicle manufacturers but the issues of standardization and service remain a concern. Battery swapping, therefore is yet to become popular for two wheelers and it would take a long time to make them a feasible option for larger EVs. The Government of India in its recent annual budget has announced that it will bring a battery swapping policy to boost use of EVs in the country. This is an important step in view of space constraints for setting up charging stations. The standardization and interoperability standards will be formulated as part of the policy. It is worth noting that absence of publicly available charging stations and battery swapping services have inhibited the consumer from buying the EVs in India.

(iv) Low Battery Life and High Cost of Replacement Batteries: The life of the battery depends upon the usage and the way it is handled. Scientifically, the life of a battery is defined by the number of charge and discharge cycles it can complete while still maintaining most of its performance[5]. A Lithium-ion battery used in EVs has an expected cycle rating of 3,000-5,000 full cycles (full discharge to full charge), which is currently the

4 "How Long Does It Take to Charge an Electric Car?" J.D. Power. Retrieved on 18-8-2022.
5 "PHEV, HEV, and EV Battery Pack Testing in a Manufacturing Environment | DMC, Inc". www.dmcinfo.com. Retrieved 17-08-2022.

highest practical battery life cycle when compared to any other type of battery. Lead-acid batteries can give up to 1,000 cycles. Most e-rickshaws in India operate on lead acid batteries but it is not capable to power a larger vehicle. Most electric vehicles are fitted with Lithium-ion batteries with an estimated life of 1500 to 2000 charge cycles. Most manufacturers also offer warranties on batteries and provide support to the EV buyer for a reasonable period of time. However, the warranty is subject to terms and conditions and customers need to be aware of all these rules beforehand. The replacement of Li-ion batteries in absence of a warranty however is costly, and currently is close to 60% of the price of the vehicle. As per an estimate, a battery for replacement in a four wheeler costs close to Rs 7.0 lakhs and for a two wheeler the price would be close to Rs 35000. This battery replacement cost is a deterrent for many consumers planning to buy EVs. The cost of batteries although declining is not likely to fall considerable as the price of Lithium has risen by over four times in recent times, due to high demand.

(v) Unsafe Batteries: The rapid growth of EVs has led to a massive demand for batteries worldwide. In a hurry to ramp up production, several manufacturers end up producing low quality batteries. Lithium-ion batteries use organic liquid electrolytes that turn inflammable at high temperatures. Poor manufacturing processes result in batteries with poor build quality which can lead to a fire in case of a crash or high ambient charging temperatures. The spate of recent incidents around the world where two wheelers made by several prominent manufacturers caught fire, revealed that poor quality batteries were responsible for the problem[6]. Recently a four wheeler manufactured by a prominent manufacturer in India caught fire as well. This was the first instance of a passenger vehicle catching fire domestically. Such incidents have dented the image of EVs manufactured in India among the prospective buyers. This may further inhibits the acceptance of EVs in medium to long term.

There are other challenges related to environment and sustainability when it comes to mass manufacturing and usage of electric vehicles. Environmentalists claim that these vehicles are not as green as they claim to be. The most critical component of an EV is its battery. The key ingredients of any EV battery today are lithium, nickel and cobalt. These are precious and scarce elements. As per an estimate, there is about 14 million tons of lithium left, which corresponds to 165 times the production volume in 2018. The extraction process of lithium also uses a lot of water and it is estimated that 500,000 gallons of water is used to mine one metric ton of lithium[7]. Excessive mining in some of the South American countries has led to severe water scarcity with local farmers and members of the community migrating to find water elsewhere. Moreover these mining companies have been accused of rampant exploitation of labor in both African and South American countries. There has been documented evidence of use of child labor and harmful effects on the health of children employed in these mines[8]. Mass manufacturing of batteries, therefore, is seen as an unsustainable activity causing long term damage to farmers and laborers both economically and physically apart from causing irreparable damage to the fragile ecosystems of developing countries where these precious metals are located.

The extraction process of lithium also uses a lot of water and it is estimated that 500,000 gallons of water is used to mine one metric ton of lithium . Excessive mining in some of the South American countries has led to severe water scarcity with local farmers and members of the community migrating to find water elsewhere.

Another issue of concern is disposal of used batteries. These batteries are toxic, and can cause fires that spread quickly especially when they are disposed off in a bunch. Several fires have been reported by municipalities in USA, which have been caused due to batteries disposed off carelessly. Careless disposal of batteries also contaminates groundwater and fresh water ecosystem.

Popularizing EVs in India: Some Suggestions

(i) Cost Reduction of and Improvement in Range of EVs in India: The price of EVs in India is exorbitant as compared to internal combustion engine driven vehicles despite subsidies by the Govt. of India. The EV manufacturers in India need to invest more in research and development for better quality batteries and powertrains to ensure higher range for the vehicles. The manufacturers should also avoid using unscrupulous means for garnering market share and volumes, at the cost of safety. All EV manufacturers must follow high standards for manufacturing batteries and ensure no unfortunate event happens again with their product. The issue of battery life can be sorted by a suitable warranty system. Manufacturers believe that the cost of production would fall once economies of scale kick in, along with improvement in quality, reliability and cost of batteries. Almost all manufacturers are working towards cost reduction and improvement of overall efficiencies.

(ii) Hybrid Petrol Vehicles to be Promoted in Short to Medium Term Through Tax Incentives: As in several countries, in the absence of battery charging infrastructure and swapping facilities, hybrid electric vehicles can be a solution for the end-user. Currently some manufacturers have launched mild and strong hybrid vehicles which use both internal combustion engines and batteries to power the vehicles[9]. These vehicles are not only highly fuel efficient but also introduce the concept of electric mobility to the buyer. Once we have created public facilities for charging along with battery swapping facilities, the consumer can move towards battery electric vehicles (BEVs) or plug-in hybrid electric vehicles (PHEVs). The Govt. of India needs to provide suitable incentives and subsidies to automobile manufacturers along with tax rebates on final product so as to make hybrid vehicles popular in India. It should also make it mandatory for all automotive manufacturers in India who produce vehicles with internal combustion engines, to produce only hybrid vehicles and in future migrate to BEVs and PHEVs.

(iii) Better Charging Infrastructure within Reach of the EV Owner: All electric vehicles including BEVs and PHEVs need charging either at home or public charging stations. Normal power AC charging, which ranges from 3kW to 22kW and is adequate for e-2Ws, e-3Ws, e-4Ws and LCVs are popular in India. In most developed countries even faster DC charging options are available. Care must be taken by all manufacturers to ensure that fast DC charging facilities in line with western countries are put up in most parts of the country. The details of charging facilities can be made available through mobile applications or through search on mobile phones or other electronic devices to ensure that the EV owner may reach the nearest facility in shortest possible time.

EVs in India present an exceptional opportunity for fueling economic growth in a sustainable manner. They are a long term economically viable solution and sustainable solution for mobility, and with some right policy interventions by policymakers and commitment by manufacturers, they can become a highly acceptable solution for a majority of Indian citizens.

(iv) Battery Swapping Infrastructure and Policy: Battery swapping seems to be a great intermediate option for improving acceptability of EVs in India. The recent policy announcement by the Government of India is a great step in the right direction[10]. Experts believe that battery swapping policy and recognizing battery or energy as a service will support EV infrastructure and adoption of EVs in both private and public transport as it helps allay the fears of range anxiety in EV owners. Care must be taken while formulating the policy as there have been bitter experiences related to battery swapping in several countries[11]. There were issues of standardization, and often quality and condition of the batteries offered at swapping station were poor, leading to consumers and manufacturers losing interest in the idea. Some two wheeler companies have experimented with this idea in India and we hope that their experience would be included in the operational aspects of final policy draft.

The emergence of electric vehicles presents both challenges and opportunities for a country like ours. We are struggling with issues of mobility along with rapidly deteriorating environment. The pollution due to large number of vehicles using fossil fuels has been affecting health of citizens and poor ambient air quality has caused damage to the health of young and old alike. This, despite the fact that India's passenger and two wheeler ownership ranks among the lowest in the world. Our public transportation systems have also failed to fulfill the rapidly growing urban and rural needs of majority of commuters in the country. Moreover, the existing diesel and petrol-run mass transportation systems have become a major polluter of the environment.

On the economic front, rising cost of petrol and diesel has forced several urban and rural commuters to look towards alternative transportation systems for their commuting needs. This has resulted in a strong interest among citizens towards shifting to electric vehicles. Electric Vehicles however suffer from several technology and sustainability issues which need to be addressed clearly through well thought of policy interventions.

What is the future of EVs in India then? How do we ensure that they are accepted by consumers using vehicles with internal combustion engines as a sustainable alternative? The answer is simple. EVs in India present an exceptional opportunity for fueling economic growth in a sustainable manner. They are a long term economically viable solution and sustainable solution for mobility, and with some right policy interventions by policymakers and commitment by manufacturers, they can become a highly acceptable solution for a majority of Indian citizens.

9 EPA and Chrysler to Take Latest Hybrid Technology from Lab to Street/Partnership to adapt fuel efficient technology". Yosemite.epa.gov (Press release). Retrieved 13-04-22.

10 "Nio's battery swapping tech in Norway". Deutsche Welle. Retrieved 17-08-2022.

11 Elis, Niv. "Death of Better Place: Electric car co. to dissolve". The Jerusalem Post. Retrieved 20-08-2022.

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Trends in Global Oil Markets

Commodity prices are more volatile as compared to prices of most financial instruments, the volatility accentuated during market events. This is because physical commodities represent the real demand and supply, which can undergo significant changes in their supply chain with little scope for painless adjustments. Tracing the timeline of oil since 2020 underlines this very character of commodity markets. If we start diagnosing it, we find a whole conundrum of intricate market forces competing against one another and price is an outcome of all of them working together.

A new global energy economy which will be efficient, interconnected, and clean is fast emerging, propelled by policy action, as well as major investments. However, the transition still has a long way to go. Even with the unequivocal pledges by the corporates, governments as well as investors towards investing in the technology for tomorrow, the world needs more affordable and efficient energy in the present. The transition towards clean energy has to be smooth and orderly.

Even with the unequivocal pledges by the corporates, governments as well as investors towards investing in the technology for tomorrow, the world needs more affordable and efficient energy in the present.

Oil is the most widely used type of fuel, which helps meet almost 31% of the global primary energy demand. Oil Markets have been through a bout of uncertainties and volatilities in the past few years. This has impacted oil producers, traders, refiners, consumers as well as Governments remarkably.

The prices of commodities are more volatile as compared to most financial instruments in any major market event, as the physical commodities represent the real demand and supply. The demand and supply of physical commodities can undergo a significant change in a major market event. This is because often the commodity supply chain is designed to function in an optimized unison in a 'normal' market. There is a little scope for painless adjustment to this perfectly choreographed ballet of supply chain in an abnormal market.

The demand and supply of physical commodities can undergo a significant change in a major market event. This is because often the commodity supply chain is designed to function in an optimized unison in a 'normal' market. There is a little scope for painless adjustment to this perfectly choreographed ballet of supply chain in an abnormal market.

This is exactly what happened during the black swan event of COVID in 2020. The timeline of oil since 2020 underlines the very character of oil. The price of the most traded commodity in the world, Oil, is a result of clash of the forces of demand and supply. If we start diagnosing it, we find a whole conundrum of intricate market forces competing against one another and price is an outcome of all of them working together.

Timeline of Oil Since 2019

2019- The year of stability and IMO preparation

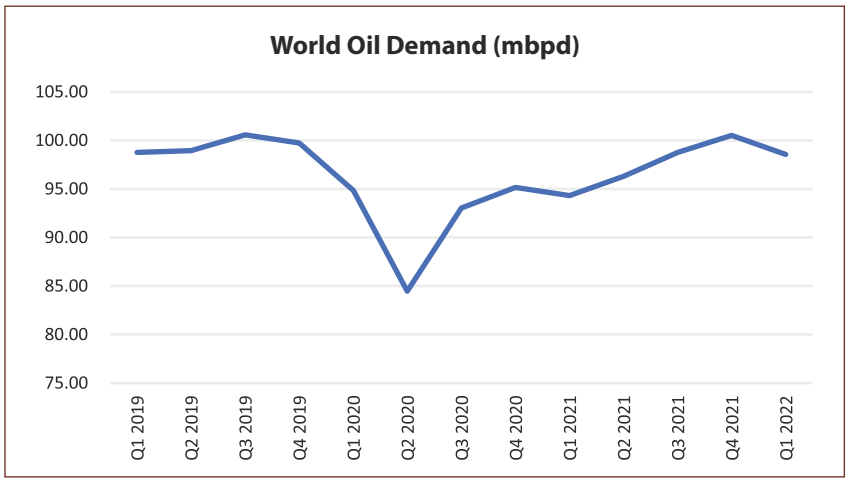
Crude Oil prices were relatively stable in 2019, mostly trading in $60-70/bbl range. In the geopolitics of oil supply, the OPEC+ agreement, formed in 2017 continued to moderate supplies and did a decent job of maintaining balance in the market. The market was preparing for a major churn in petroleum products however, emanating from approaching the applicability of the International Maritime Organization (IMO) 2020 regulations, which were to start from the beginning of 2020. The IMO regulations had tasked the shipping industry to switch from 3.5% Sulphur Marine Fuel oil to using 0.5% Sulphur Fuel. The only way to get away with higher sulphur fuel was to install a bulky scrubber aboard a ship, which can strip the exhaust of the sulphur and reduce air pollution.

The talk of IMO Regulations, the resulting change in flows of some crude grades, and the imminent tightness of Gasoil pool in the oil market hogged all the limelight in major industry gatherings.

2020 – The Black Swan year

The global economy suffered its deepest contraction since the Great Depression due to the COVID-19 pandemic, and no country escaped unscathed. Oil being the fuel that powers mobility, suffered heavily due to exposure to lockdowns. At its trough in April, the oil demand was down more than 20 million bpd from its usual, which is very significant given the tight balances that this market operates at. The demand rebounded and considerably recovered by the end of the year. On an yearly basis, demand fell by around 8 million bpd in 2020.

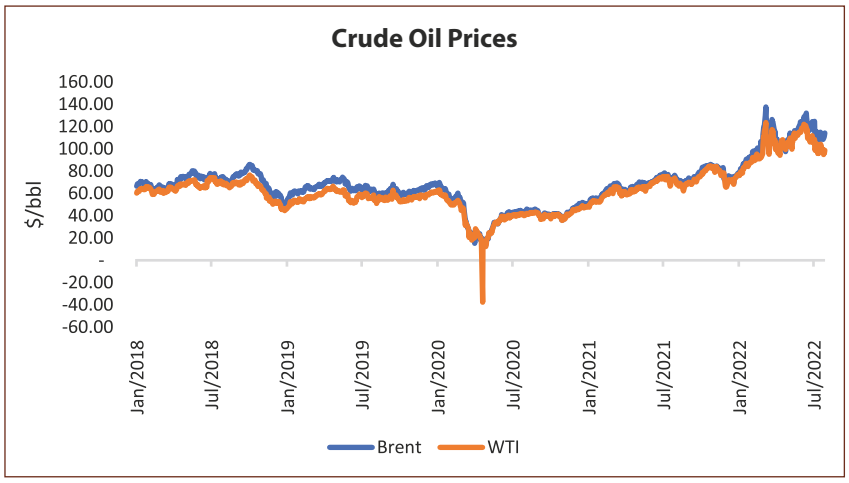
At its trough in April, the oil demand was down more than 20 million bpd from its usual, which is very significant given the tight balances that this market operates at.



Source Data: International Energy Agency

At a more granular level, the impact as most prominent for Jet-Fuel with most demand loss of the tune of more than 4.5 million bpd as air travel was severely curtailed. Road transport fuels such as Gasoline and Gasoil too suffered a loss of around 4 million bpd combined, as personal mobility as well as economic activity was severely curtailed as a result of lockdowns in large parts of the global economy. Oil refiners who coming into 2020 were fixated at the prospect of healthy refining margins owing to IMO 2020, suffered dearly as collapsing demand along with the new capacities coming up in Middle East and Asia, resulted in Refining Margins as well as refinery utilization rates plummeting. This stress resulted in the permanent closure of some refining infrastructure as well, particularly of the older facilities in some of the mature markets.

On the supply side, the sudden curtailment in demand was not adequately countered at the first instance by the supplies, and the world saw a market share fight between Saudi and Russia, leading to historical plummeting of the global oil prices. The world saw oil inventories brimming to the top, with severe shortage of both on-land storage infrastructure as well as on-ship storage resulting in historical jump in tanker shipping rates as well. The widely watched NYMEX WTI turned negative $42/bbl at the fag end of April delivery as the long holders found it impossible to square off their positions in a market marked by dearth of buyers. This price paradox arose out of over saturated oil inventories in the storage hub of Cushing, where buyers with outstanding longs have to take delivery at the contract expiry.



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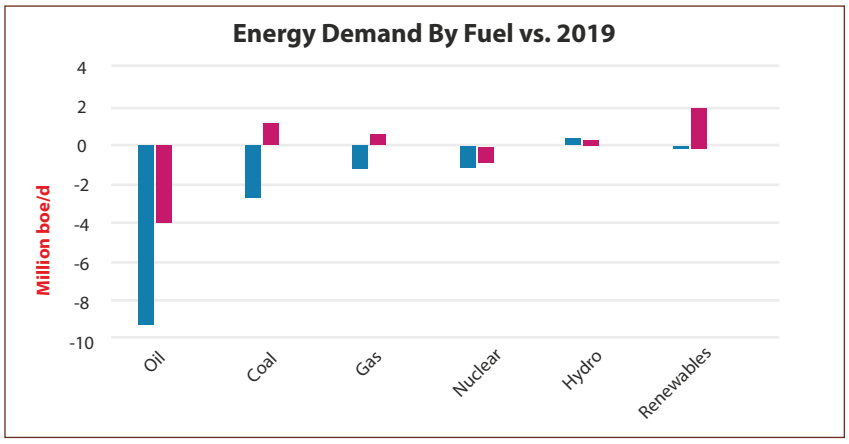
The exodus in oil prices posed worrying signs for the viability of the prospects of the industry, with large parts of oil producing assets unable to recover costs. With some US intervention, OPEC+ agreed on a headline cut of 9.6 million b/d, with gradual tapering. The quantum of cut as well as the discipline of players since the 2020 deal has been remarkable and against the anecdotal evidence of member producers 'cheating' at the lucrative prospect of maximizing revenues.

This discipline in the market along with the demand recovery towards the end of the year, as well as stocking up of Strategic Petroleum Reserves (SPRs) by some of the consuming countries, led by mammoth flows into China, meant that oil prices largely trended between $40-50/bbl for the second half of the year.

2021 – After the storm

After the significant demand loss in 2020, focus of global energy markets going into 2021 was on the pace of demand recovery, though the period was also characterized by risks of COVID waves hampering the recovery, speed of liquidation of mammoth oil inventory built up, as well as any potential long term change in consumer demand behaviour emanating out of a once-a-lifetime black swan event.

Recovery did happen for all the energy sources, just that the pace of demand recovery was significantly unequal for different fuel types. While oil continued to still lag the pre-pandemic demand of 2019, the demand for other hydrocarbons exceeded their pre-covid levels. This was a result of a strong industrial demand while people mobility (including aviation) still continued to underperform.



(Chart Source: S&P Global Commodity Insights)

The unequalness in demand recovery was also a signal for OPEC+ to maintain strict compliance to production cut agreements. Some quarters of the market already called 2019 as the 'peak demand year' and expected intense climate action to result in further demand loss as well as delinking of economic grown and fossil fuel consumption.

OPEC+ continued to maintain its impeccable compliance to production quotas, and demand recovery performed better than expected, fueled by massive liquidity pushed by the central bankers to fight the demand slowdown in 2020. The demand recovered significantly, and the inventories deprecated steadily. With OPEC taps not opening at an accelerated pace, it was a bullish signal for oil, and we saw oil prices recovering and even exceeding to their pre-pandemic levels. The saga of low oil prices during 2020 and the aggressive climate related targeting by some of the largest oil players meant that there were significant under-investments in new oil production, either due to demand-linked risk of stranded assets or environment-linked shareholder activism. This presented a potential undersupply risk for the oil markets, particularly in the short run, as the world was not transitioning to clean energy sources at a fast enough pace, to not warrant any supply growth for Oil.

Underpinned by this demand recovery as well as continuing supply discipline meant the oil inventories receded and the oil prices continued their journey northwards topping their pre-pandemic levels. The consuming countries led by USA were not happy with the fate of prices, barely 18 months after the exodus. The threat of buyer cartelization as well as coordinated release of SPRs too was insufficient to destabilize the resolve of OPEC+ to drain oil global oil inventories.

2022 – Making or Breaking

2022 for oil was always thought to be tighter, going by the pace of demand recovery , and the discipline amongst producers. No oil pundits however predicted 100+ on oil. The Russian Invasion of Ukraine turned out to be very significant for geopolitics of oil supplies and prices. Russia which is 1/3 of the 'big-three' oil producers, immediately came on loggerheads with much of the western oil world. There were quick divestments in Russian stakes by many major oil corporations, and many others vowed to self-sanction themselves against Russian Oil, even ahead of Regulatory Action. European economies which were highly dependent on Russia to satiate their energy demand through multiple cross-continental pipelines found itself being unable to wean-off Russian hydrocarbon supplies.

What this meant was that even though on paper the overall demand-supply situation hadn't changed much, however in reality, some of the seaborne exports out of Russia was shunned by the market, with only limited takers. These dotted lined supplies gave rise to what is popularly known as a two-tiered market. On one tier were those averse to Russian oil, but paying top dollar for the next best alternative. On the other tier were refiners accepting Russian oil, who enjoyed large discounts of even up to USD 40 /bbl to the benchmark crude oil prices. This phenomenon not only resulted into a rapid change in seaborne trade flows for crude oil, but also led to concerns about energy affordability, security and reliability.

This is particularly relevant as the impact of Russia-Ukraine conflict was even greater for other hydrocarbons as compared to oil. With the European Union heavily dependent on Russia for pipeline gas supplies, the risk of no

With the European Union heavily dependent on Russia for pipeline gas supplies, the risk of no supply sky-rocketed for Europe overnight, and we saw an armada of Seaborne LNG supplies heading towards Europe after the Ukraine crisis. This led to the other parts of the world being starved of Gas, which led to significant Gas-to-Coal and Gas-to-Oil Switching. The whole basket of hydrocarbon commodities jumped in the northern hemisphere summers of 2022 threatening the world with severe energy inflation.

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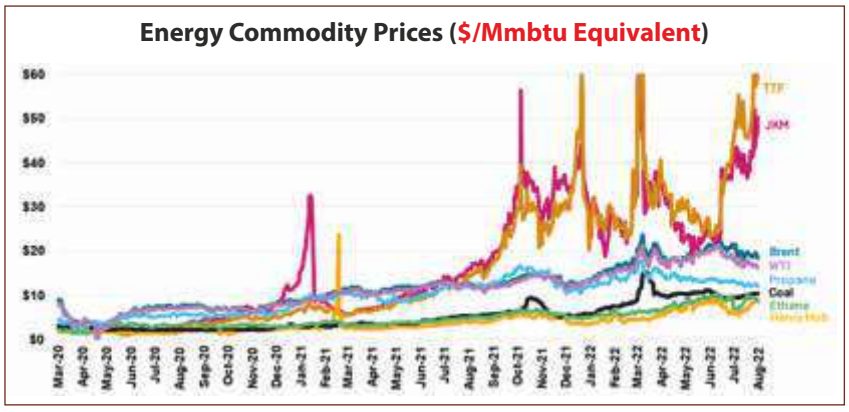
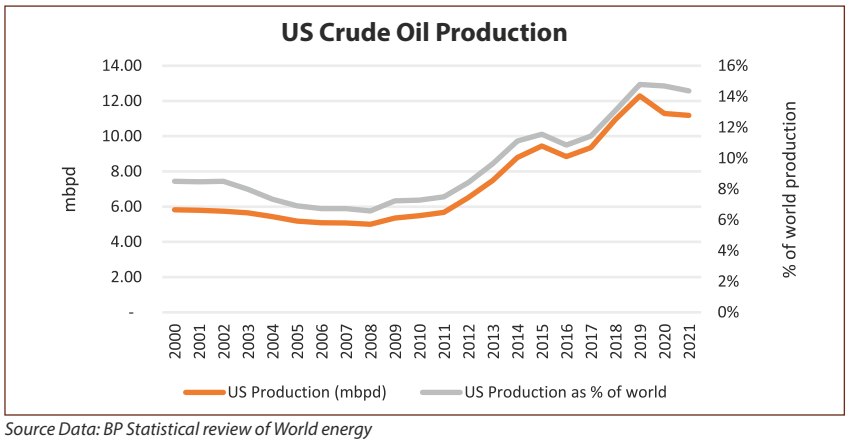


Source: S&P Global Commodities Insights

US Crude Oil – The Beacon of Non-OPEC+ Supply Hope

The story of US as a prominent supplier for crude oil emanated from the rise of the shale era in early 2010s when US crude oil production skyrocketed. After a point of saturating all the domestic refiners, there was no alternative destination for the increasing US domestic production, other than to let the same be exported to the international markets. US lifted the embargo on crude oil exports in 2015, and the same flowed freely to oil starved European and Asian refiners. This quickly re-adjusted the oil flows for some of the major oil importing hubs, and WTI became a staple diet for many refiners. US Crude production has grown by leaps and bounds since then, and is today a closely-tracked indicator of market tightness.



Source Data: BP Statistical review of World energy

The prominence of US crude to the world market has also resulted in the inclusion of the US WTI Midland crude into Platts Dated Brent Crude oil price benchmark, which is the world's most prominent physical crude oil benchmark consisting of North Sea produces low sulphur crude oil grades. This inclusion is effective June 2023, and will likely reflect market realities for the state of sweet crude oil.

Elsewhere too, the US crude oil is also one of the most tracked oil flow by OPEC+, as the US shale oil has a relatively short cycle and can look very different in terms of Capex and Opex as compared to conventional oil anywhere in the world.

What was unprecedented though was the usage of US SPR as a political tool in 2021 to signal prices to OPEC+, in coordination with other consuming countries, including India.

Strategic Petroleum Reserves – The Supplier of the Last Resort?

Another story that played out quite prominently over the upheaval in oil demand-supply and prices was the role of Strategic Petroleum Reserves (SPRs). US which has the world's largest formal and transparent SPR, had its long-stated policy to wind down strategic reserves as the US' net dependence on imported oil has diminished greatly after the domestic US production jumped. Despite this, we saw some build-up in US reserves in 2020 to absorb the severe demand shock. What was unprecedented though was the usage of US SPR as a political tool in 2021 to signal prices to OPEC+, in coordination with other consuming countries, including India. US administration continued with more of the same in 2022, and is on target to release about 1 million barrels per day of crude oil continuously over several months, mainly to alleviate the concerns on high prices. For comparison, this is around the same quantity that oil-rich Libya exports.

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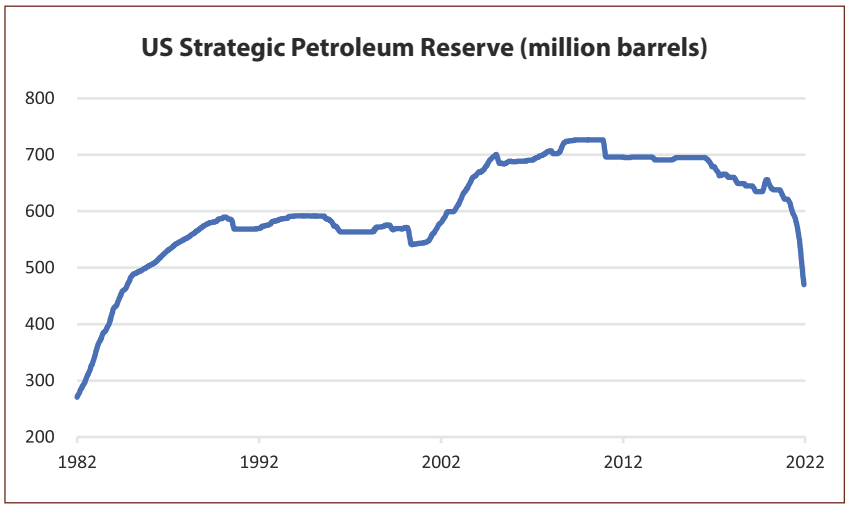


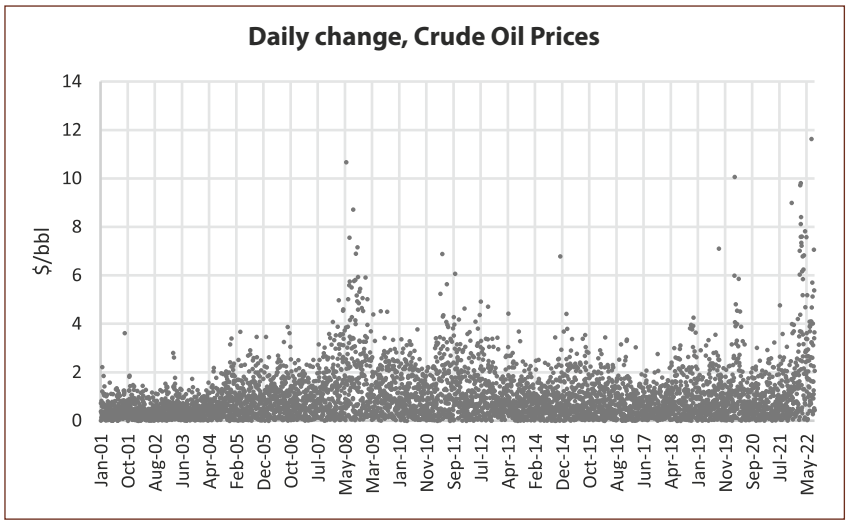
Data Source: US Energy Information Administration (EIA)

While the US SPR has been very transparent, an even larger hold for oil appears to be available in China, which absorbed a large number of stranded barrels during the height of 2020 demand destruction and helped balance the market. The volume of oil stored in massive Chinese SPRs can only be estimated at best by the number of oil tankers arriving and backing the apparent domestic demand and exports of finished petroleum products. There is limited indication, however, that China has started using SPRs en-masse for meeting domestic demand in 2022, particularly as the demand still lags due to the zero COVID policy that China still complies with.

This change in strategic orientation of SPR as a price signal tool was new for the world of oil trading, as the SPRs was always meant to be used as safekeeping for dealing with supply related emergencies. There is a major risk associated with this politicization of an important 'reserve' for oil – the world is fast losing the cushion that can absorb shocks arising out of any unknown emergencies constraining physical supply of oil.

Volatility Trumps All

Amidst all these headlines of rapidly changing market fundamentals, as well as the geopolitical risks surfacing, the price volatility of oil in the recent past has been quite high.



The historic volatility in prices has created significant risks and uncertainties for the producers, traders, consumers as well as the governments. Oil is a heavily taxed as well as a heavily subsidized commodity depending on which part of the world one decides to visit. This, along with the high impact of oil prices on the consumer inflation, means that many of the global economies had to suffer major shocks in 2022. Some of the largest trading houses too had a rude awakening as the quantum of liquidity required for carrying positions swelled greatly.

Volatility in prices at its very fundamental is a result of a tight market, and the increasing tendency of the industry to shy away from committing to additional investments along with a fairly strong short term demand trajectory for oil means that the tight balances are here to stay at least in the short run. There are of course downside risks to demand from the numerous economic downturn projections, and an upside risk to supply from the potential unlocking of Iranian oil to the markets. The likelihood of any of these, or the possibility of another major market event impacting the intricately balanced supply-demand equation for oil, can be anybody's guess.

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Recent Trend in Crude Oil Price: Analysis and Observations

An impact analysis has been carried out to assess the trend in global crude oil price fluctuations in two different times, i.e., (2001-2015), and (2001-2020). Further, the study has aimed to examine the reasons behind the crude oil price fluctuations. After completing the analysis, it has been found that the overall trend of crude oil price fluctuations during (2001-2015) and (2001-2020) was upward rising generally. A time series analysis is also done to estimate price movements. Despite the analyzed results, crude oil prices may abruptly change in reality due to any sudden occurrence of international unpredicted events.

Introduction

Globally, crude oil is considered as one of the most important fuel resources. From historical viewpoint, it has contributed to more than one third of the global energy consumption. Being a significant source of energy resource, crude oil is regarded as a leading import and export commodity of several countries. Subsequently, the importance of this commodity increased tremendously as it developed a large financial market in oil and oil derivatives, including instruments like futures, options, and forwards. (Corporate Finance Institute, 2021). The global crude oil market is anticipated to reach worth around $1407.65 billion within 2022, with fossil fuels demand as the prime driver of the market. The crude oil market in Asia Pacific region accounts for the highest share in the global crude oil market. In order to increase the oil and gas production, digital oilfield technology is being used by the oil and gas extraction companies during recent times. (The Business Research Company, 2020).

Global prices of crude oil tend to fluctuate due to several reasons including surging demand, low production compared to overall demand, international events such as war, advent of pandemic, etc. Historically, the global crude oil prices had registered significant fluctuations for several times because of the occurrence of different international events. In this research study, the analysis has been carried out mainly to find out the trend in crude oil price fluctuations and its impact on the global economy. In order to do so, two separate timeframes i.e., (2001-2015) and (2001-2020) have been chosen to carry out the trend analysis. Further, a time series analysis has been done based on the data of crude oil prices in 1981-2020. After carrying out the trend analysis and time series analysis of the crude oil prices during those times separately, the outcomes have been assessed and explained accordingly.

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Objective

The objectives of this study are as below:

1) To discuss the importance of crude oil market in global energy sector,
2) To analyze the trend in crude oil price fluctuations in historical perspective,
3) To examine the reasons behind the crude oil price fluctuations, and
4) To assess the impact of crude oil price fluctuations on global economy.

Methodology

In this study, the secondary data of global crude oil prices over three separate times namely, (2001-2015), (2001-2020), and (1981-2020) have been selected for the statistical analysis. The data have been obtained from the source 'BP Statistical Review of World Energy 2016' and 'Statistical Review of World Energy – BP'. The statistical analysis comprises of (1) a comparative analysis between global crude oil price and world crude oil consumption percentage (global oil consumption out of total global population) during 2001-2015, (2) trend analysis in global crude oil consumption percentage (global oil consumption out of total world population) during 2001-2015, (3) trend analysis in crude oil prices during 2001-2020, and (4) Estimating likely crude oil prices during 2021-2025 by using the Autoregressive Integrated Moving Average (ARIMA) model. The statistical analysis has been carried out with Microsoft Excel (version 2016) and SPSS software (version 21).

Importance of Crude Oil Market in Global Energy Sector

Major companies operating in the global crude oil market comprise of BP Plc, Exxon Mobil Corporation, Royal Dutch Shell, Rosneft, Kuwait Petroleum Corporation. Besides that, a large number of countries have established their supremacy in the global crude oil market are – Australia, Argentina, Austria, Brazil, Belgium, Czech Republic, Canada, China, Chile, Colombia, Denmark, Egypt, France, Finland, Germany, Hong Kong, Indonesia, India,Ireland, Italy, Israel, Japan, Mexico, Malaysia, New Zealand, Netherlands, Nigeria, Norway, Philippines, Peru, Poland, Portugal, Russia, Romania, Saudi Arabia, South Africa, Singapore, South Korea, Sweden, Spain, Switzerland, Turkey, Thailand, USA, UAE, UK, Vietnam, Venezuela. (The Business Research Company, 2020).

In terms of crude oil market segmentation, the global crude oil market is divided based on geography and type. Geographically, the global crude oil market is categorized under different segments including North America, South America, Eastern Europe, Western Europe, Asia Pacific, Middle East, and Africa. Among all these regions, Asia Pacific was recognized the largest region in the international crude oil market. Type wise, the global crude oil market is classified under various segments such as transportation, industrial, and others.

Among all these sectors, the transportation market accounts for the highest share in the global crude oil market. With growing demand for fossil fuels to meet up the energy requirement from around the world particularly in the developing countries like India and China, the scope and potential for the global crude oil market is anticipated to rise significantly in future. (The Business Research Company, 2020).

Most of the crude oil reserves in the world are located in the Middle East, where approximately 48% of oil reserves are in known and identified reserves. This is followed by North America, Africa, Central and South America, Eurasia, Asia and Oceania, and Europe. In this context, the Organization of Petroleum Exporting Countries (OPEC) have controlled roughly 40% of the global crude oil, accounts for nearly 75% of the world's proven oil reserves, and exports about 55% of the oil traded globally.

Trend of Crude Oil Price Fluctuations – A Historical Perspective

The OPEC is the chief influencer of the global crude oil price fluctuations. The OPEC is an association, which as of 2021, is comprised of 13 countries including Angola, Algeria, Congo, Equatorial Guinea, Gabon, Iraq, Iran, Kuwait, Libya, Nigeria, Saudi Arabia, the United Arab Emirates, and Venezuela. As per the 2018 statistics, OPEC had controlled around 80% of the global oil supply reserves. (Lioudis, N., 2021).

Historically, crude oil supply disruptions, specifically caused by political events, had actually caused oil prices to change radically. For example, several international events including the Arab oil embargo (1973), the Iranian revolt (1978), the Iran-Iraq war (1980-88), and the Gulf wars (1990-91) had been causing oil fluctuations. The Asian financial crisis and the global economic crisis during 2007-08 had further triggered the oil fluctuations. (Bajpai, P., 2022).

Besides, strong economic growth and industrial production have increased the demand for oil. In this context, the US Energy Information Administration (EIA) had stated, "Oil consumption in the Organization for Economic Cooperation and Development (OECD) countries declined between 2000 and 2010, [while] non-OECD oil consumption increased more than 40%. China, India, and Saudi Arabia had the largest growth in oil consumption among the countries in the non-OECD during this period". (Bajpai, P., 2022).

The dramatic fall in oil prices in 2014 was attributed to lower demand for oil in China and Europe, coupled with a stable supply of oil from OPEC. The excess amount of oil supply had eventually triggered oil prices to fall sharply. While demand and supply had impacted oil prices, it was the oil futures that set the oil price. (Lioudis, N., 2021).

In addition, reports on production figures, extra capacity and investment could all affect crude oil prices during the short term. Some of the most closely followed reports were the International Energy Agency (IEA) oil market report, OPEC's monthly oil report, and weekly inventory data from both the American Petroleum Institute (API) and the US EIA. (Bajpai, P., 2022).

Reasons behind the Crude Oil Price Fluctuations

Several factors including OPEC output or supply, changing scenarios in oil demand from emerging and developing countries, the US crude and products inventories, refinery utilization rate, global geopolitics, speculative buying and selling, and weather conditions are often attributed as factors affecting global crude oil price market over the years.

In this context, while examining the possible reasons behind the crude oil price fluctuations, industry analysts highlight three major factors including the current supply, future supply, and expected demand that traders use to estimate oil prices. The current supply highlights the total output of crude oil worldwide. In this connection, OPEC produces around 40% of the global crude oil output and subsequently, possesses a significant impact on determining the international oil prices. Besides, access to future supply depends on oil reserves which can easily be accessed to increase the oil supply if prices get very high. Moreover, traders follow the global crude oil demand, specifically from the US and China. (Amadeo, K., March 2022).

Besides, occurrence of unrest has been causing oil prices to soar from time to time. For instance, in March 2011, unrests in several countries such as Egypt, Libya, and Tunisia had actually caused oil prices to rise more than $100 per barrel in early March, which had increased to roughly $113 per barrel by late April. (Amadeo, K., March 2022).

In addition, natural and anthropogenic disasters often impact crude oil price movement. In this connection, the advent of COVID-19 pandemic has caused significant impact on crude oil prices. For instance, in January 2020, a large number of governments had started limiting travel and closing businesses in order to control the COVID-19 pandemic. Consequently, the demand for crude oil had started plummeting. During the first quarter of 2020, global oil consumption was around 94.4 million barrel per day, which was below the average consumption of 5.6 million barrel per day recorded in 2019. A fall in demand was exacerbated by excess supply. On March 6th 2020, Russia had declared that it would raise production in April 2020. Further, in order to keep up its market share, OPEC had announced

that it would also step up crude oil production. (Amadeo, K., March 2022).

Impact of Crude Oil Price Fluctuations on Global Economy

In this study, a comparative analysis has been performed between the global crude oil prices and world crude oil consumption percentage (global oil consumption out of total global population) during 2001-2015 (**Table 1**). The main aim behind performing this analysis is to identify the nature of global crude oil consumption in terms of international crude oil price movement. From this analysis, it is found that the international crude oil consumption had steadily increased from 2001 to 2007. However, the crude oil consumption had declined particularly in 2008 and 2009 specifically due to the occurrence of global financial crisis in 2008. Subsequently, the global crude oil prices had drastically dropped in 2009 from 2008. But the prices had recovered in 2010 from the previous year. However, oil prices had remained volatile during 2011-2015 mainly due to several reasons related to global economic events.

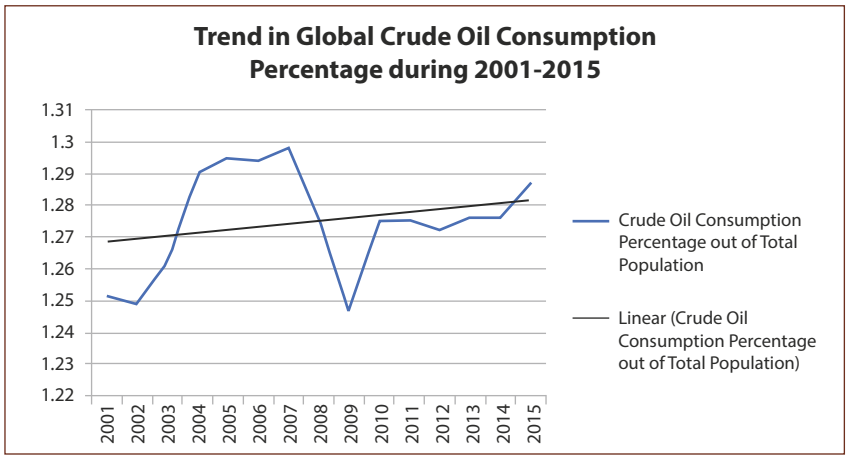
Besides, a trend analysis of global crude oil consumption percentage has been carried out specifically to observe the absolute oil consumption pattern of countries worldwide (**Figure 1**). From the trend line of Figure 1, it has been found that the overall global crude oil consumption pattern was upward rising during 2001-2015.

Table 1 : A Comparative Analysis between Global Crude Oil Price and World Crude Oil Consumption Percentage (Global Oil Consumption out of Total Global Population) during 2001-2015

Year	Global Oil Consumption (BP Statistics (2016))	Global Crude Oil Price (BP Statistics (2016))	World Population (historical estimates)	Global Oil Consumption Percentage (Global Oil Consumption out of Total Population)
2001	77862512.21	32.713	6222912459	1.251
2002	78762792.17	32.967	6302062210	1.249
2003	80569448.95	37.137	6381477292	1.262
2004	83367891.72	48.011	6461454653	1.290
2005	84725723.35	66.167	6542205330	1.295
2006	85727791.8	76.588	6623819401	1.294
2007	87087312.1	82.749	6706251239	1.298
2008	86578405.62	107.064	6789396380	1.275
2009	85700422.88	68.133	6873077808	1.246
2010	88764840.5	86.408	6957137521	1.275
2011	89790312.34	117.229	7041509491	1.275
2012	90662685.46	115.280	7126144677	1.272
2013	92048929.48	110.552	7210900157	1.276
2014	93109470.93	99.063	7295610265	1.276
2015	95008050.82	52.386	7380117870	1.287

Developed by the Author from the source "BP Statistical Review of World Energy 2016", https://ourworldindata.org/grapher/world-crude-oil-price-vs-oil-consumption, (Retrieved on June 6th 2022).

Figure 1: Trend in Global Crude Oil Consumption Percentage (Global Oil Consumption out of Total World Population) during 2001-2015

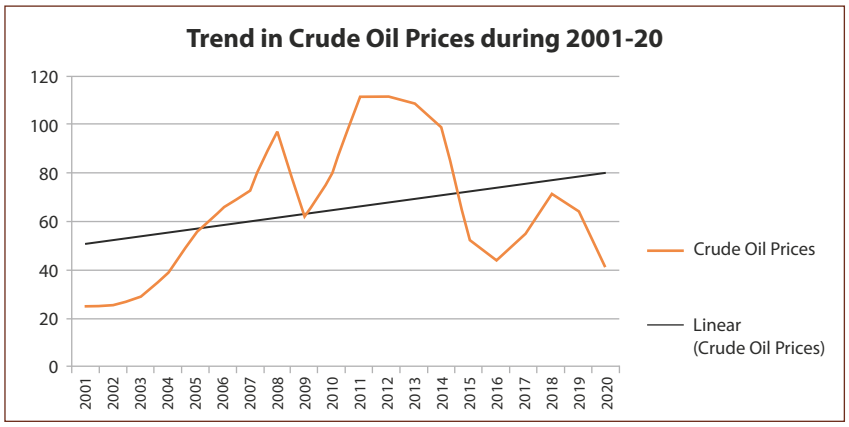


Developed by the Author from the source "BP Statistical Review of World Energy 2016", https://ourworldindata.org/grapher/world-crude-oil-price-vs-oil-consumption, (Retrieved on June 6th 2022).

In addition, trend analysis has been carried out with the help of 20 years (2001-2020) crude oil prices data (**Figure 2**). The main objective behind this calculation is to find out the price movement trend of crude oil during 2001-2020. After the calculation, it has been found that the overall trend of crude oil price movement was upward rising during the given period. However, price was volatile in nature in some years mainly because of several reasons worldwide. For instance, the financial crisis of 2008 had led to a drop in the demand of industrial commodities. As a result, the demand for crude oil had plummeted. Besides, the Libyan uprising in 2011 led to a surge in the prices of crude oil. Moreover, tensions with Iran in 2012

had accounted for a rise in crude oil prices during the same time. In 2014, crude oil prices had again sharply declined mainly due to the fall in global real economic activity. (Baumeister, C. and Kilian, L., 2016).

Figure 2: Trend in Crude Oil Prices during 2001-20



Developed by the Authors from the source "Statistical Review of World Energy - BP", https://ourworldindata.org/grapher/crude-oil-prices, (Retrieved on June 6th 2022).

While studying the trend of crude oil prices during 2001-2020, it can be stated that while the trend may continue, prices would continue to be affected by global demand and supply. The advent of the COVID-19 pandemic during 2020 had raised doubts whether the expected demand of crude oil increase. Due to the lockdown, restrictions, and less uses of fuel-based vehicles, the demand for the crude oil did not increase globally during the immediate post-2020 period. On the other hand, it was anticipated that the improved COVID-19 situation might enhance the crude oil demand globally after the lockdowns were lifted., with associated impact on oil prices.

Estimation of Crude Oil Prices

In this statistical analysis, the ARIMA model has been taken into consideration. For this purpose, 40 years (i.e. 1981-2020) crude oil prices data has been selected to estimate prices of 2021-2025. The source of the data is ***'Statistical Review of World Energy - BP'.*** After the calculation, the R-squared value is observed as 0.846, which signifies that the model is a good fit **(Tables 2 and 3)**. It means that approximately 85% of the variation in the output variable is explained by the input variables.

While studying the trend of crude oil prices during 2001-2020, it can be stated that while the trend may continue, prices would continue to be affected by global demand and supply. The advent of the COVID-19 pandemic during 2020 had raised doubts whether the expected demand of crude oil increase.

The model provides estimates which are in tune with the US EIA's estimation of Brent crude oil nominal price in 2025.

Table 2

MODEL FIT											
Fit Statistic	**Mean**	**SE**	**Minimum**	**Maximum**	**Percentile**						
					5	10	25	50	75	90	95
Stationary R^2	.509	.	.509	.509	.509	.509	.509	.509	.509	.509	.509
R^2	.846	.	.846	.846	.846	.846	.846	.846	.846	.846	.846
RMSE	11.937	.	11.937	11.937	11.937	11.937	11.937	11.937	11.937	11.937	11.937
MAPE	27.364	.	27.364	27.364	27.364	27.364	27.364	27.364	27.364	27.364	27.364
MaxAPE	87.065	.	87.065	87.065	87.065	87.065	87.065	87.065	87.065	87.065	87.065
MAE	9.123	.	9.123	9.123	9.123	9.123	9.123	9.123	9.123	9.123	9.123
MaxAE	31.075	.	31.075	31.075	31.075	31.075	31.075	31.075	31.075	31.075	31.075
Normalized BIC	5.144	.	5.144	5.144	5.144	5.144	5.144	5.144	5.144	5.144	5.144

Table 3

MODEL STATISTICS						
Model	**Number of Predictors**	**Model Fit statistics**	**Ljung-Box Q(18)**			**Number of Outliers**
		R^2	Statistics	DF	Sig.	
CrudeOilPrices-Model_1	0	.846	16.269	16	.434	0

Conclusion

As of June 2022, the past two years had been predominantly volatile for the crude oil industry. While analyzing the fact, the market experts found that the COVID-19 pandemic had led to a significant crash in crude oil prices. Subsequently, the gradual improvement in global economic activities, specifically because of improved vaccination rates and decreased pandemic-oriented restrictions and lockdowns, had resulted in global crude oil prices to rebound. The increase in international crude oil prices was exacerbated particularly due to the fact that the global oil demand had begun quickly outpacing the global supply. In tune with the fact, the industry analysts argue that the uncertainty behind the Russia-Ukraine war is actually driving the present surge in crude oil prices. In this context, they highlight that Russia is considered the second largest producer of crude oil in the world, thereby supplying approximately 11% of the worldwide oil requirements. (Seneviratne, B., 2022).

It can only be predicted that despite rising demand and past trend of rising prices, several international factors and unknown events can pose uncertainties, causing volatility in prices. It is this volatility in crude oil prices that is the only certain element in the oil industry, and an element of risk which needs to be appropriately managed.

With this background, it can only be predicted that despite rising demand and past trend of rising prices, several international factors and unknown events can pose uncertainties, causing volatility in prices. It is this volatility in crude oil prices that is the only certain element in the oil industry, and an element of risk which needs to be appropriately managed.

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Sinking cost and tying hands: Indian strategic oil reserves are not sunk costs

Several countries, including India have created crude oil storage facilities or "Strategic Petroleum Reserves (SPRs)" in order to mitigate the impact of disruptions in global oil supply. Although there are significant costs associated with creating and maintaining SPRs, they have been providing several tangible as well as intangible benefits, as evidenced on a number of occasions.

Introduction

Several countries, including India, vie to achieve higher world order by acquiring military power (arms and ammunition) and spending huge sums on building robust institutions (R&D centres, academic institutions, policy think tanks, etc.). Additionally, if a country is endowed with natural resources, the country starts from a position of inherent strength in the order of the committee of nations. In recent times, the most important resource is crude oil. With crude oil as the available natural resource, the political and economic clout of the country is higher. It has also been observed over time that resource rich countries, including oil rich nations, have extracted huge political mileage. As a matter of fact, in current times, many countries have been guarded and diplomatic while expressing their views on Russia's invasion of Ukraine; not because they support the war, but because of their dependence on Russia for oil and natural gas. In fact, dependence on Russia is an understatement; many countries, especially from European Union, are entirely dependent on Russian oil and natural gas and cannot live without the same. Consequent to the Russian invasion of Ukraine, all major Russian banks were removed from SWIFT, and all major global (Western) banks were directed to not deal in Russian Ruble; yet President Putin had the ability to call the shots and proclaim *"Unfriendly countries will have to pay in Rubles for gas supplies"*; such is the power of a resource rich country and Russia is not an exception.

The economic power of oil exporting countries over oil importing ones was acutely felt during the Arab-Israel War of 1973-1974 when OAPEC[1] members within OPEC[2] not only imposed an oil embargo on a number of countries including USA, The Netherlands, Portugal and South Africa for supporting the Israeli military action, but also reduced the daily crude oil production leading to increase in crude oil price by 400% i.e., from USD 2.90 a barrel in October 1973 to USD 11.65 a barrel by January 1974.

The International Energy Agency

Understanding the importance of impact of crude oil shortage on economies of oil importing nations, the International Energy Agency (IEA), as an intergovernmental organization, was set up in 1974 with the objective of ensuring security of oil supplies for member countries[3]. Thus, IEA paved the path for member nations to create crude oil storage facilities or *"Strategic Petroleum Reserves (SPRs)"*. Further, IEA also operates a collective action mechanism under the *"Agreement on an International Energy Program Treaty"* to mitigate disruptions in oil supply by undertaking coordinated release for SPRs. Of late, IEA has broadened its mandate to promote energy efficiency measures, advance R&D and commercialization of energy technologies as well as promote digital solutions to support low carbon energy transition among member countries.

In addition to inducting countries as full members, IEA also inducts countries striving to build SPRs as associate members; India, China, Brazil, Morocco, Indonesia, Thailand and Singapore are associate members of IEA.

An interesting point to note is that even though it was only after the establishment of IEA as an intergovernmental body that brought SPRs into international arena, the idea of stockpiling crude oil for emergency purposes was discussed as early as in 1944 by Harold Ickes, the then US Secretary of the Interior and Petroleum Minister for War, when he stressed on the need to create and maintain a petroleum reserve for USA. However, the US government did not do much in this regard till the 1970s. It was the oil embargo due the Arab – Israel war of 1973 – 1974 that acted as the impetus for the actual creation of SPRs by IEA members. As part of IEA membership, member countries, specifically oil importing countries, are required to maintain an inventory of at least 90 days of oil based on previous calendar year's import. However, member nations tend to hold inventory much higher than the minimum requirement (See details in Table A).

While IEA mandates 90-days of inventory, the IEA members / associate members are free to decide the manner of holding the inventory. IEA members / associate members may choose to hold the stockpile in any of the three mechanisms:

1. Government stock,
2. Industry stock, or
3. Through leasing mechanism also known as ticketing.

Government stock is directly owned by the country, financed through budgetary allocation and are held exclusively for emergency purposes. Industry stock is owned by organizations operating in the oil sector (upstream, mid-stream and downstream companies) of a country. In addition to inventory to be maintained for their commercial

1 OAPEC is the acronym for Organization of Arab Petroleum Exporting Countries.
2 OPEC is the acronym for Organization of the Petroleum Exporting Countries.
3 IEA founding member countries are Austria, Belgium, Canada, Denmark, Germany, Ireland, Italy, Japan, Luxembourg, The Netherlands, Norway, Spain, Sweden, Switzerland, Turkey, UK and the USA. Subsequently other countries such as Greece, New Zealand, Australia, Portugal, Finland, France, Hungary, Czech Republic, Korea, Slovak Republic, Poland, Estonia, and Mexico, and Lithuania, taking the total membership to 31. Source: https://www.iea.org/about/history.

operation, oil sector companies are mandated to hold industry stock at their own refineries or at bulk terminals. In many countries, such as India, the Government is a major shareholder of these oil sector companies and hence it ensures that these companies maintain industry stock. Many IEA members / associate members also meet a part of their 90-day stockholding obligations through leasing agreements, referred as tickets. As part of ticketing agreements, normally an oil producing country agrees to store/hold fixed amount of crude oil/refined product on behalf of an IEA member / associate member. IEA member / associate member has the option of taking delivery of the physical stock in times of need and the oil producing company has the obligation to deliver physical stock. Ticketing can be both domestic and foreign; in domestic ticketing, the oil producing country holds the reserve within national boundaries of the IEA member / associate member country, while in a foreign ticketing, oil producing country holds the emergency reserve outside its national boundary. In case of a foreign ticketing, IEA requires both countries enter into bilateral agreement so that seller delivers the physical stock to the IEA member / associate member in times of need.

India Story

Though India joined IEA in 2017 as an associate member, the Government of India (GoI) having understood the importance of energy security had in 2004 incorporated the *Indian Strategic Petroleum Reserves Limited (ISPRL)*, a wholly owned Special Purpose Vehicle (SPV) under Ministry of Petroleum & Natural Gas (MPNG), GoI as the sole custodian of critical sovereign crude oil reserves of GoI. Phase-I of SPR creation saw ISPRL constructing underground rock caverns at Visakhapatnam (Andhra Pradesh), Mangalore (Karnataka) and Padur (Karnataka) with a combined storage capacity of about 9 – 10 days of crude oil requirements for the country. These three SPR facilities were commissioned in 2015, 2016 and 2018 respectively at a total cost of INR 40.9835 billion. In Phase-II, ISPRL is constructing similar rock caverns at Chandikhol (Odisha) and Padur-II (Karnataka) for storing about 12 days crude oil requirement, thus increasing the total storage capacity to around 21 – 22 days of requirements. Interestingly, in a smart move, during April – May 2020, ISPRL, under instruction from GoI, had filled Phase – I SPR facilities, taking advantage of low crude oil prices at an average price of USD 19 per barrel[4].

Additionally, apart from the 9 – 10 days of crude inventory stored in the Phase - I facilities, the oil marketing companies such as IOCL, HPCL, BPCL etc. are required to hold about 65 days of oil requirement. Further, as a part of domestic ticketing mechanism, ISPRL has entered into an agreement with Abu Dhabi National Oil Company (ADNOC), whereby ADNOC has hired part of ISPRL storage facility at Mangalore for storing crude oil.

Creation and maintenance of SPRs are no doubt expensive propositions. The emergency stock can be stored in three different storage structures:

1. Underground rock caverns,
2. Underground salt caverns, and
3. Above ground storage tanks.

Geographical conditions of a country have to be amenable for underground rock or salt caverns. Otherwise, a country can store the strategic reserve in above ground storage tanks. Choice of storage structure is also dependent on whether a country chooses to store crude oil or refined products. In general, storage costs include land purchase/land lease costs, cost of construction of crude oil/refined product storage caverns/units, cost of supporting infrastructure like jetties / truck / railcar loading facilities to deposit and release crude oil / refined products, as well as regular operations and maintenance costs. Apart from the fixed costs of creating SPR facilities and the regular operations and maintenance costs, a very large chunk of the costs of maintaining SPR arises from the cost of filling in crude oil / refined product inventory; this normally accounts for around 75% - 80% of the total cost. SPRs may also incur "Refreshment[5]" cost. While crude oil can be stored for long without any quality degradation, refined products need to be changed periodically due to loss of quality as an effect of ageing. Therefore, the higher the share of refined products in overall emergency stock, larger is the refreshment cost. Normally countries lacking substantial domestic refining capacity prefer to hold refined products, thus incurring higher refreshment costs.

Benefits of SPRs

The cost of maintaining crude oil reserve varies across countries based on factors mentioned above. The variability in the type of storage / product and hence the variability in the costs makes the process of ascertaining the total cost of storage quite complicated. However, quantifying the benefit of having SPR is easier said than done. SPRs provide both tangible as well as intangible benefits. Many countries use the SPR during natural calamities to tide over supply disturbances; for example, USA released SPR crude during Hurricanes Lily (2002), Ivan (2004), Gustav (2008), Ike (2008), Isaac (2012) and Harvey (2017) to moderate the impact of oil (petroleum / diesel) price hikes following these hurricanes. Similarly, in May 2019, Hungary released oil from its SPR to mitigate the shortfall arising due to lost imports through Russian pipelines as the oil pipelines were contaminated with chloride.

In addition to individual country-specific requirements, IEA members also undertake coordinated release when global supply of crude oil is affected severely due to either war or war-like situations, as well due to natural calamities. Since its inception, IEA members have undertaken four coordinated releases; the first one was undertaken during 1991 Gulf war, the second in 2005 in the aftermath of

4 https://www.news18.com/news/business/india-to-fill-strategic-oil-reserves-by-early-may-says-petroleum-ministry-2579083.html.
5 Refreshment refers to the regular renewal of refined product stock in order to maintain quality specification.

IEA members undertake coordinated release when global supply of crude oil is affected severely due to either war or war-like situations, as well due to natural calamities. Since its inception, IEA members have undertaken four coordinated releases; the first one was undertaken during 1991 Gulf war, the second in 2005 in the aftermath of Hurricane Katrina and Rita which practically destroyed the oil rigs and refineries in the Gulf of Mexico, the third during the Libyan civil war in June 2011, and the most recent one being in March – April 2022[1] due to Russia's invasion of Ukraine.

Hurricane Katrina and Rita which practically destroyed the oil rigs and refineries in the Gulf of Mexico, the third during the Libyan civil war in June 2011, and the most recent one being in March – April 2022[6] due to Russia's invasion of Ukraine. In fact, in the most recent coordinated release due to the Russian invasion of Ukraine, IEA members have agreed to release a combined volume of 180 million barrels over a period of six months to tide over the supply bottlenecks and ensuing price rise. In fact, not only is the back–to–back coordinated release within a gap of one month undertaken by IEA unprecedented, releasing 180 million barrels (approximately 9% of total emergency reserve held by IEA members) is also unprecedented. In fact, the intention of IEA in alleviating supply shock due to Russian invasion of Ukraine has been aptly articulated by IEA Executive Director, Fatih Birol, in his statement, *"The unprecedented decision to launch two emergency oil stock releases just a month apart, and on a scale larger than anything before in the IEA's history, reflects the determination of member countries to protect the global economy from the social and economic impacts of an oil shock following Russia's aggression against Ukraine"*[7].

Despite the coordinated releases, there have been times when the effectiveness of such action by IEA in softening crude oil price has been questioned; the same question is being asked in the context of the most recent release decision by IEA. Given the scale of supply disruption arising out of the Russian invasion of Ukraine, IEA's release of 1 million barrel per day (bpd) over 6 months is inadequate as Russia is the second largest crude oil exporter, exporting about 7.8 million bpd[8]. Notwithstanding the IEA's effectiveness in reducing oil price, IEA's actions do act as a signal to the world market that as a crude oil buyer group, IEA members / associate are taking a cooperative approach to thwart oil price rise and increase crude oil availability.

Considering the significant cost required to create, maintain and fill SPRs, a pertinent question is often raised – as a developing country, does India need SPRs? One often hears the argument against SPR creation in India – the argument being that even without being an IEA member or even without creating SPRs, India can enjoy being a "free rider" to IEA initiatives. This is based on the premise that any action by IEA in reducing crude oil price will anyway benefit India irrespective of its membership status vis-à-vis of IEA, and hence there is no need to invest in SPRs!! On the other side, India is the 3rd largest crude oil consumer in the world; given that, can or should India take a passive approach to mitigate risks arising from crude price and availability volatility? Petroleum politics to secure oil supplies from a foreign country has been in vogue since the 1970s, yet India has mostly remained on the sidelines. With increasing geopolitical difficulties, petro-aggression is assuming bigger proportion, it is time for India as one of largest crude consumer to actively manage this risk.

Even though many countries are reducing their dependence on fossil fuel and transitioning to renewable source of energy, India's crude oil demand is expected to increase in near future. According to IEA, India's oil demand will increase 50% by 2030 from 2019 level, i.e., from 4.8 million bpd to 7.2 million bpd and to about 9.2 million bpd by 2050[9].

In international diplomacy, sinking cost and tying hands have been often used by countries to credibly signal their strategic intent to world at large. A typical example of sinking cost is when a country mobilizes a massive army spending a large sum on defense. These activities are not only are costly but also irrecoverable in nature i.e., basically sunk costs. In case of tying hand, a country, being a part of larger alliance commit itself to ethos of alliances and may have to incur significant costs in future to abide by the alliance's need. For example, many countries are expressing their keenness

If countries take pride in creating fortresses for storing tons of gold bars, creating underground crude oil storage for one of the essential commodities should also be viewed as strategic choice and not a sunk cost.

6 IEA invoked its collective release mechanism twice: during March 1 and April 1, 2022.
7 IEA confirms member country contributions to second collective action to release oil stocks in response to Russia's invasion of Ukraine, https://www.iea.org/news/iea-confirms-member-country-contributions-to-second-collective-action-to-release-oil-stocks-in-response-to-russia-s-invasion-of-ukraine.
8 https://www.weforum.org/agenda/2022/04/which-petroleum-products-does-russia-supply-to-world/
9 https://www.businessworld.in/article/IEA-Forecasts-50-per-cent-Rise-In-India-s-Oil-Demand/13-10-2021-408576/
10 The greatest responsibility of the Alliance is to protect and defend NATO's territory and populations. Article 5 of NATO's founding charter, the Washington Treaty, sets out the Alliance's collective defense commitment. It states that an attack on one shall be considered an attack on all. Available at https://www.nato.int/nato_static_fl2014/assets/pdf/pdf_2015_12/20151130_1512-10things-eng.pdf

to be part of NATO[10] as by being part of NATO they will not only be protected from external aggression, but they will also support other NATO members in times of need.

Drawing a parallel, India creating underground mega storage rock caverns is an example of sinking cost while being an IEA member is akin to tying hand. Both are no doubt costly, but this is the least India can do to mitigate crude oil risk. With limited domestic crude oil production capacity, having access to crude oil stored in its domestic soil will give the much-needed maneuverability to India. In case there is a severe supply bottleneck, without SPR crude, India's action will be hurried and may be detrimental to India's political ideology. If countries take pride in creating fortresses for storing tons of gold bars, creating underground crude oil storage for one of the essential commodities should also be viewed as strategic choice and not a sunk cost.

Table A: Number of days of storage by IEA member nations

VEHICLE TYPE			
Country	**Days of Storage**	**Country**	**Days of Storage**
Australia	75	Mexico (*)	0
Austria	124	Japan	211
Belgium	190	Korea	187
Canada (*)	0	Netherlands	838
Czech Republic	140	New Zealand	87
Denmark	473	Norway (*)	0
Estonia (*)	0	Poland	125
Finland	200	Portugal	120
France	131	Slovak Republic	178
Germany	129	Spain	123
Greece	176	Sweden	130
Hungary	203	Switzerland	184
Ireland	104	Turkey	98
Italy	148	United Kingdom	888
Lithuania	176	USA (*)	1069
Luxembourg	98		

Data Source: https://www.iea.org/articles/oil-stocks-of-iea-countries
**Note that Canada, Mexico, USA, Estonia and Norway are exempted from 90-day holding period as oil-exporting countries. Even though USA is exempted from holding 90-day inventory, it still holds 1069 days of inventory.*

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Viability and sustainability of Ethanol blending in emerging Nations: An Indian Perspective

Domestic biofuels provide a strategic opportunity to the country, as they reduce the nation's dependence on imported fossil fuels. In tune with National Policy on Biofuels, petrol with 10% ethanol blend is currently being retailed by various Oil Marketing Companies, the target being raised to 20% blending of ethanol by 2025. Given the wide scope of fuel blending in various transport sectors, and as is being observed from Brazil's success with fuel blending, there are considerable gains to be made and opportunities to be reaped if India were to create a favourable regulatory and retail ecosystem for safe and effective adoption of ethanol-blended fuel.

Energy demand in our country is rising due to an expanding economy, growing population, increasing urbanization, evolving lifestyles and rising spending power. About 98% of the fuel requirement in the road transportation sector is currently met by fossil fuels and the remaining 2% by biofuels. Today, India imports approx. 85% of its oil requirement. Domestic biofuels provide a strategic opportunity to the country, as they reduce the nation's dependence on imported fossil fuels. In addition, when utilized with appropriate care, biofuels can be environmentally friendly, sustainable energy sources.

Ethanol is one of the principal biofuels, which is naturally produced by the fermentation of sugars by yeasts or via petrochemical processes such as ethylene hydration. It has medical applications as an antiseptic and disinfectant. It is used as a chemical solvent and in the synthesis of organic compounds, apart from being an alternative fuel source. Currently petrol with 10% ethanol blend (E10) is being retailed by various Oil Marketing Companies (OMCs) in India, wherever it is available. As per Gazette Notification dated 5th Feb-2019, Ethanol Blending at 10% is allowed in whole country except Andaman Nicobar and Lakshadweep.

Currently BIS was modified and the Ethanol blending in motor spirit is allowed at 9% +/-1% i.e. maximum ethanol blending at 11% is permitted so as to achieve 10% blending average on a pan-India basis. As a result the average ethanol blending for Ethanol Supply Year 2021-22 (upto July22) achieved in the country is 10.16% .

The average ethanol blending for Ethanol Supply Year 2021-22 (upto July22) achieved in the country is 10.16% .

National Policy on Biofuels - 2018

The National Policy on Biofuels-2018 (NPB-2018) approved by the Government envisages an indicative target of 20% blending of ethanol in petrol by 2030. Now the same has been advanced to Year 2025. E-20 sales is likely to commence from April-2023 to achieve the target of 20% Ethanol blending by 2025 instead of earlier plan of 2030. This National Policy on Biofuels - 2018 builds on the achievements of the earlier National Policy on Biofuels and sets the new agenda consistent with the redefined role of emerging developments in the Renewable Sector.

The National Policy on Biofuels-2018 (NPB-2018) approved by the Government envisages an indicative target of 20% blending of ethanol in petrol by 2030. Now the same has been advanced to Year 2025.

Salient features National Policy on Biofuel-2018 are listed below-

- ***Categorization:*** The Policy categorises biofuels as ***"Basic Biofuels"*** viz. First Generation (1G) bioethanol & biodiesel and "Advanced Biofuels" – Second Generation (2G) ethanol, Municipal Solid Waste (MSW) to drop-in fuels, Third Generation (3G) biofuels, bio-CNG etc. to enable extension of appropriate financial and fiscal incentives under each category.
- ***Scope of Raw Materials:*** The Policy expands the scope of raw material for ethanol production by allowing use of Sugarcane Juice, Sugar containing materials like Sugar Beet, Sweet Sorghum, Starch containing materials like Corn, Cassava, damaged food grains like wheat, broken rice, rotten potatoes, unfit for human consumption for ethanol production.
- ***Protection to Farmers:*** Farmers are at a risk of not getting appropriate price for their produce during the surplus production phase. Taking this into account, the Policy allows use of surplus food grains for production of ethanol for blending with petrol with the approval of National Biofuel Coordination Committee.
- ***Viability Gap Funding:*** With a thrust on Advanced Biofuels, the Policy indicates a viability gap funding scheme for 2G ethanol Bio refineries of Rs.5000 crore in 6 years, in addition to additional tax incentives, higher purchase price as compared to 1G biofuels.
- ***Boost to Biodiesel Production:*** The Policy encourages setting up of supply chain mechanisms for biodiesel production from non-edible oilseeds, Used Cooking Oil, short gestation crops.

NPB-2018 was amended further vide gazette notifications dated 15.06.22. The source of feedstocks for production of various biofuels have been further enlarged.

Bio-Ethanol Generation Routes

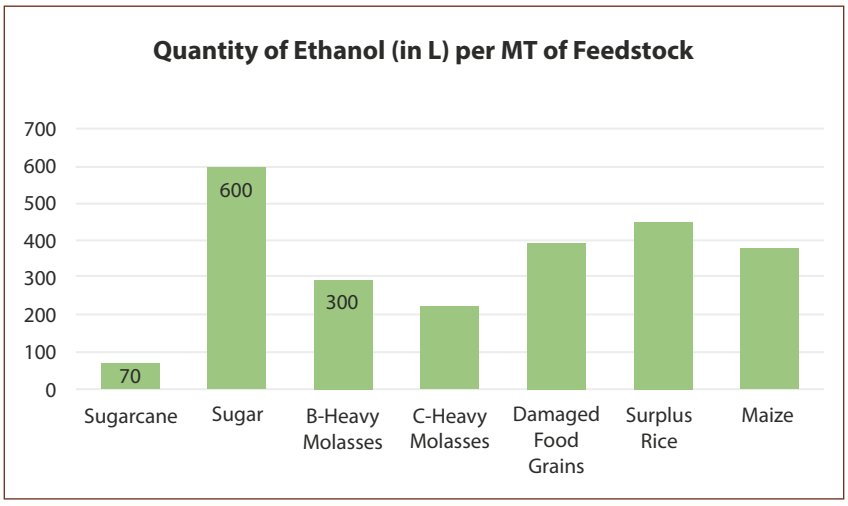
The various routes and feedstocks for production of Ethanol are as under.

- ***1-G Bio-Ethanol:*** First-generation (1G) Bio-Ethanol is produced from biomass such as sugar containing materials (like sugar cane juice, molasses, sugar beet etc.) and starch containing materials (such as corn, cassava, rotten vegetables such as potatoes, damaged food grain, surplus rice etc.). 1G feedstocks are potentially to be considered to be in competition with food and thus giving impetus to Fuel Vs food debates.
- ***2-G Bio-Ethanol:*** Second Generation (2G) feed stocks include agricultural residues like rice & wheat straw, cane trash, corn cobs & stover, cotton stalk, bagasse, Empty Fruit bunches (EFB), etc.
- ***3-G Bio-Ethanol:*** 3G biofuels are drawn from industrial waste, municipal solid waste, algae etc. 2G and 3G biofuels are recognized as being more advanced.

Currently OMCs are receiving ethanol from 1G source only as 2G & 3G source plants are under commissioning.

1G Ethanol Feedstock

Department of Food and Public Distribution (DFPD) is the nodal department for promotion of fuel grade ethanol producing distilleries in the country. Government has allowed ethanol production/procurement from sugarcane-based raw materials viz. C & B heavy molasses, sugarcane juice / sugar / sugar syrup, damaged food grain, surplus rice with Food Corporation of India (FCI) and Maize. The raw material wise conversion efficiency is placed below:



Source: Expert Committee Report on "Roadmap for Ethanol Blending in India: 2020-2025".

Feedstock	Cost/ MT of the feedstock (Rs/MT)
Sugarcane Juice/ Sugar/ Sugar Syrup	2850*
B Molasses	13,500
C Molasses	7123
Damaged Food Grain	16,000
Surplus Rice	20,000
Maize	15,000

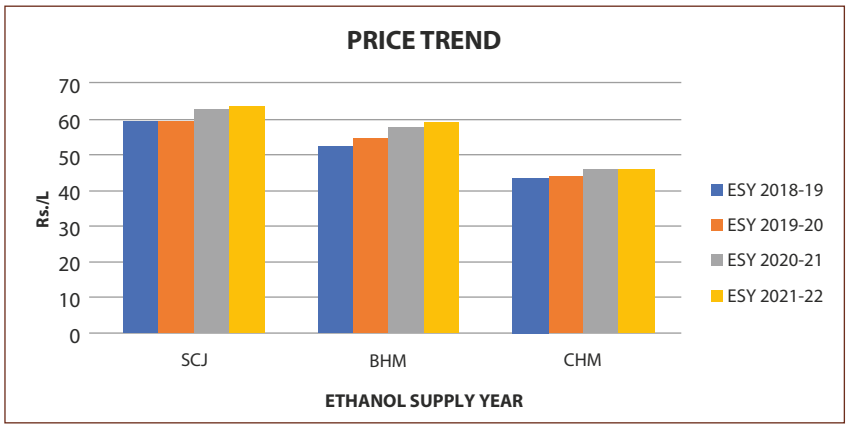
**Price of Sugarcane at 10% Sugar Recovery*

Ethanol Pricing

From 2018-19, the Government has been taking steps on pricing, incentives, opening alternative routes for ethanol production to increase the availability of Ethanol domestically. The Ministry of Petroleum and Natural Gas (MOPNG) has advised administered price of Ethanol sourced from various feed stocks for the Ethanol supply year. The last 4 Sugar Year pricing of different feedstocks are as under.

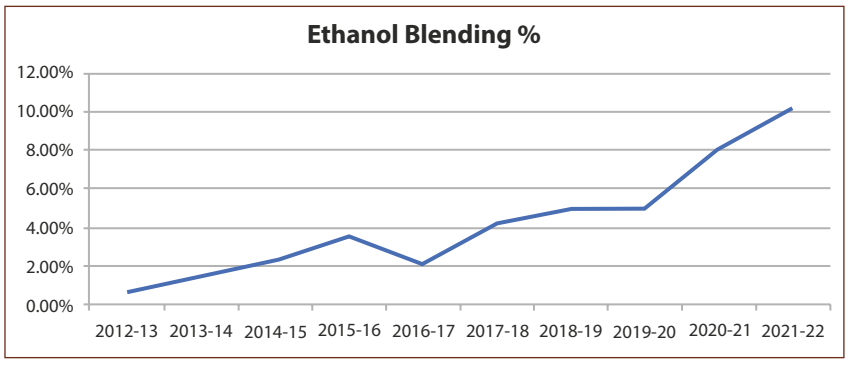
ETHANOL BASIC PRICE (RS/ LITRE)				
Feed Stock	**ESY 21-22**	**ESY 20-21**	**ESY 19-20**	**ESY 18-19**
Sugar /Sugar Syrup / Sugar Cane Juice (SCJ)	63.54	62.65	59.48	59.19
B-Heavy Molasses (BHM)	59.08	57.61	54.27	52.43
C-Heavy Molasses (CHM)	46.66	45.69	43.75	43.46
Damaged Food Grain	52.92	51.55	50.36	47.13
Surplus Rice	56.87	56.87	NA	NA
Maize	52.92	51.55	NA	NA

OMCs are paying the above rates as well reimbursing transportation and GST (present rate: 5%) to ethanol vendors for their supply to depot / terminals.



Pan India Ethanol Blending Status:

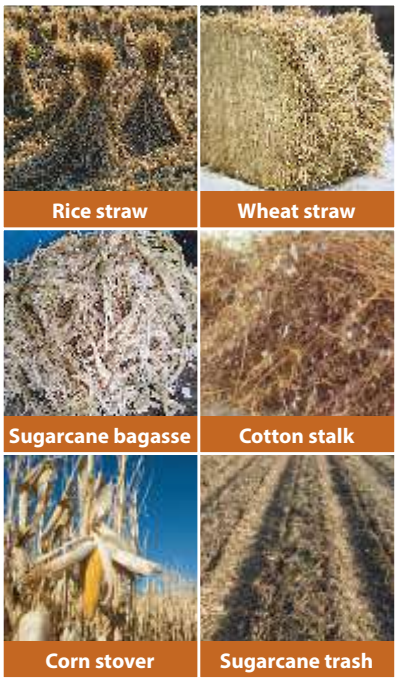
Ethanol Supply Year (ESY) (Dec to Nov)	Tendered Qty (crore Lit) (crore Lit)	Qty Allocated (crore Lit) OMCs	Qty Supplied/ Blended (crore Lit)	Blending % age PSU OMCS
2012-13	103	32.0	15.4	0.67%
2013-14	115	70.4	38.0	1.53%
2014-15	128	86.5	67.4	2.33%
2015-16	266	130.5	111.4	3.51%
2016-17	280	80.7	66.5	2.07%
2017-18	313	161.04	150.5	4.22%
2018-19	329	268.99	188.57	5.00%
2019-20	511	210.56	173.03	5.00%
2020-21	457.64	372.81	302.3	8.10%
2021-22 (upto July22)	459.0	450.7	299.1	10.16



2G Ethanol Feedstocks

2G based ethanol is produced from cellulose, hemicellulose, lignin or pectin materials such as from Agricultural, forestry wastes or residues, or purpose-grown non-food feedstock (e.g. Short Rotation Coppice, Energy Grasses).

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. Already Rs. 1969.50 Crores have been earmarked for this scheme. These plants can use feedstocks such as rice straw, wheat straw, corn cobs, corn stover, bagasse, bamboo and woody biomass, etc.



2G Ethanol Plants

Indian Oil Corporation Ltd (IOCL) is setting up 100 KLPD 2G Ethanol Plant at Panipat, Haryana with paddy straw as feedstock.

Numaligarh Refinery Ltd. (NRL) is also coming up with one 2G Ethanol plant in Assam with Bamboo as feedstock. Similarly Bharat Petroleum Corporation Ltd (BPCL) and Hindustan Petroleum Corporation Ltd (HPCL) have plan to set up their 2 G Plants at different places.

3G Ethanol Plant

Indian Oil 3G plant is about production of ethanol from the HGU (Hydrogen Generation Unit) PSA (Pressure Swing Adsorption) Off-Gases available in the Panipat Refinery of IOCL. The ethanol will be produced by the gas fermentation technology. The 3G Plant Capacity is 128 KL/Day. The plant will be first of its kind in the world to use refinery off-gases to produce Ethanol.

Ethanol Demand Projections in India

The ethanol requirement year on year is projected progressively with increased blending of 10% from ESY 2020-21 to 20% by ESY 2020-25 as under:

Ethanol Supply Year (Dec to Nov)	Projected Petrol Sale (Crore Litre)	Blending (in %)	Ethanol Requirement (Crore Litre)
2021-22	4374	10	437
2022-23	4515	12	542
2023-24	4656	15	698
2024-25	4939	20	988
2025-26	5080	20	1016

Source: Expert Committee Report on "Roadmap for Ethanol Blending in India: 2020-2025"

As the EBP rolls out in the country, vehicles need to be produced with rubberized parts, plastic components and elastomers compatible with E20 and engines optimally designed for use of E20 fuel.

Thus, as per the above requirement of 1016 Cr Ltrs by ESY 2025-26, OMCs have published the EOI to enter into long term bipartite agreement with upcoming dedicated ethanol plants in ethanol deficit states to procure Denatured Anhydrous Ethanol for 648.5 Cr Litre/ESY against which total 1236 Cr Litre/ESY has been received. However, OMCs have signed bipartite agreement with 130 bidders with approximate 430 Crore /Annum off-take quantity.

Flex- Fuel Vehicles

To go beyond 20% blending after ESY - 2020-25, there is an urgent need to introduce flexi fuel vehicles in the country. Currently produced two-wheeler and passenger vehicles in the country are designed optimally for E-5, with rubber and plastic components compatible with E-10 fuel; their engine can be calibrated for E-10 for better performance. As the Ethanol Blending Programme (EBP) rolls out in the country, vehicles need to be produced with rubberized parts, plastic components and elastomers compatible with E20 and engines optimally designed for use of E20 fuel. Introduction of flexi fuel vehicles are necessary to enhance blending percentage beyond 20%.

OMCs (IOC, BPC & HPC) have also commissioned retail outlets with pure Ethanol (E-100) to be used as standalone fuel at Pune City. This will demonstrate India's commitment towards ethanol blending and give confidence to auto makers to go for manufacturing of flexi fuels vehicles as well as vehicle compatible to E-100.

Introduction of FFVs

A **flexible-fuel vehicle (FFV)** is an alternative fuel vehicle with an internal combustion engine designed to run on more than one fuel, usually gasoline blended with either ethanol or methanol fuel and both fuels are stored in the same common tank. Modern flex-fuel engines are capable of burning any proportion of the resulting blend in the combustion chamber as fuel injection and spark timing are adjusted automatically according to the actual blend detected by a fuel composition sensor.

A flex-fuel car looks just like any other kind of car. The main differences between the two lie with the engine and fuel system. The internal combustion engine of a flex-fuel vehicle is designed to run on more than one type of fuel -- usually gasoline plus ethanol or methanol fuel, all of which are stored in the same tank. When one starts driving, a sensor mounted in the fuel line reads the fuel blend-the ethanol/ methanol/ gasoline ratio, or the fuel's alcohol concentration and sends a signal to an electronic control module. The electronic control module then adjusts the fuel trim, or the engine's fuel delivery control, to compensate for the different fuel mixtures. Components that comprise the fuelling system of flex-fuel vehicles are also crafted to be ethanol-compatible.

Production of EBP Compatible Vehicles in India

Vehicles made in India since 2008 are material compatible with E10 and fuel-efficient compliant with E5

As the EBP rolls out in the country, vehicles need to be produced with rubberized parts, plastic components and elastomers compatible with E20 and engines optimally designed for use of E20 fuel. The cost of E20 compatible vehicles is expected to be higher in the range of Rs. 3000 to Rs. 5000 for four-wheelers and Rs. 1000 to Rs. 2000 for two-wheelers, over and above the cost of ordinary vehicles tailored to run on 100% gasoline.

Retro-fitment on existing Vehicles

The existing vehicles on roads are compatible to E10 but their engine/vehicles are not tuned to E10 for optimum performance efficiency. Developing parts with upgraded material for a large number of vintage variants with a wide range of fuel system component designs and then getting the customers to get their vehicles upgraded, is a mammoth task.

MANUFACTURES IN INDIA

TVS Apache RTR 200 4V

TVS Apache RTR 200 4V comes in an ethanol version. The TVS Apache RTR 200 Fi E100 is India's first and currently only ethanol-powered production motorcycle. It is priced at Rs 1.2 lakh (ex-showroom) and is available only in Karnataka, Maharashtra and Uttar Pradesh. The E100's 197.75 cc single-cylinder air and oil-cooled engine uses twin-spray twin-port electronic fuel-injection technology. Maruti, Bajaj and Mahindra have also announced launch of Flexi Fuel Vehicles in India very soon.

All the 3 OMCs (IOC, HPC & BPC) have commissioned E-100 facilities in Pune in 1 retail outlet each on 05.06.21.

Source: https:// www.stocksmantra.in/flexible-fuel-engine-flex-engine-manufacturers-in-india/

GLOBAL SCENARIO

Though technology exists to allow ethanol FFVs to run on any mixture of gasoline and ethanol, from pure gasoline up to 100% ethanol (E100), North American and European flex-fuel vehicles are optimized to run on E85, a

blend of 85% anhydrous ethanol fuel with 15% gasoline. This upper limit in the ethanol content is set to reduce ethanol emissions at low temperatures and to avoid cold starting problems during cold weather.

Ethanol Scenario in Brazil

One country, which has successfully integrated biofuels into its fuel economy, is Brazil. It has efficiently leveraged its traditions and dominance in sugarcane production into a biofuel economy without compromising on food security.

To mitigate high dependence on oil imports, Brazil turned to its traditional sugarcane to revolutionize its fuel economy. The quest for a higher productivity and sugar-ethanol balance led Brazil to revolutionize its biomass production for ethanol and develop a new variety of sugarcane, popularly known as 'energy cane', which is low on sucrose but high on biomass.

It has efficiently leveraged its traditions and dominance in sugarcane production into a biofuel economy without compromising on food security.

With productivity up to 350 tonnes of biomass per ha, against 80 tonnes per ha of traditional sugarcane, it offered a perfect balance for ethanol production without compromising sugar production. It enabled Brazil to gradually augment its production and blend.

In 2019 alone Brazil saved about 0.5 million barrels per day of gasoline with a savings of $13 billion in imports. 78% of Brazilian automobiles today run on 27% of ethanol blend.

With a mandatory blending of 27 per cent ethanol with gasoline, in 2019 alone Brazil saved about 0.5 million barrels per day of gasoline with a savings of $13 billion in imports. 78% of Brazilian automobiles today run on 27% of ethanol blend.

High biomass productivity of energy-cane is the biological factor that contributes to the high positive lifecycle energy balance of ethanol produced from it, with a resultant positive balance of greenhouse gases emission. With residual cane-waste (Bagasse) also becoming commercially valuable for power generation and other commercial uses, it has been possible to transform energy-cane production into a multiproduct enterprise in Brazil.

Brazil legislated that the ethanol content in gasoline sold in the country should be in the range of 18% to 27.5%, which is currently at 27%. Concurrently, the use of 100% hydrous ethanol by flex-fuel vehicles in Brazil has increased the average share of ethanol in transportation, to 46% in 2019. The fleet of flexible-fuel vehicles in Brazil is the largest in the world, representing over 80% of the total number of new vehicles sold in the country in 2019. Brazilian flexible-fuel vehicles are optimized to run on any mix of E20-E25 gasoline and up to 100% hydrous ethanol fuel (E100).

Number of Registered New Light Vehicles in Brazil from 2014 to 2020, by Fuel Type:

Year	Flex autos produced	Flex light trucks produced	Total flex-fuel light -duty vehicles produced	Flex vehicles as % total light vehicles	Flex motor -cycles produced	Flex motor cycles as % total
2003	39,853	9,411	49,264	2.9		
2004	282,710	49,797	332,507	15.2		
2005	820,791	60,150	880,941	37.1		
2006	1,291,913	100,142	1,392,055	56.3		
2007	1,764,494	172,437	1,936,931	69.1		
2008	2,026,768	216,800	2,243,648	74.7		
2009	2,298,942	242,211	2,541,153	84.0	188,494	12.2
2010	2,311,721	315,380	2,627,111	77.1	332,351	18.2
2011	2,215,548	335,234	2,550,782	80.7	956,117	44.7
2012	2,418,397	313,663	2,732,060	83.9	814,110	48.2
2013	2,616,845	333,766	2,950,611	84.2	NA	
2014	2,291,115	346,607	2,637,722	88.2	NA	
2015	1,785,284	212,473	1,997,757	85.4	NA	
2016	1,605,855	164,813	1,770,668	84.0	NA	
2017	1,923,143	207,035	2,130,178	81.9	NA	
Total 2003-17	25,693,379	3,080,009	28,773,388	70.3	2,291,072*	31.8

Sources: Cars and light trucks: ANFAVEA (2003-2017)
Motorcycles: ABRACICLO 2009, 2010, 2011 and 2012.

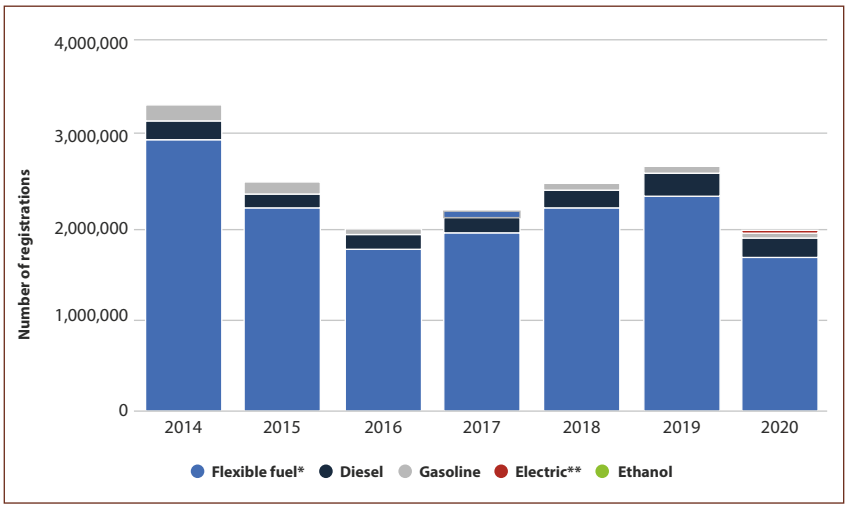
Notes:

(1) Includes exports and excludes flex imports from the other Mercosur countries.
(2) Total includes gasoline, neat ethanol, flex, and diesel-powered vehicles.
(3) *Total between 2009 and 2012 only

Source: https://www.statista.com/statistics/712070/number-of-registered-automobiles-in-brazil/

Ethanol Scenario in the United States

U.S. flex-fuel vehicles are optimized to run on a maximum blend of 15% gasoline with 85% anhydrous ethanol. The fleet of flexible-fuel vehicles in the United States is the second largest in the world after Brazil, and there were more than 21 million flex-fuel vehicles registered in the country by the end of 2017. Despite the growing fleet of E85 flex-fuel vehicles, actual use of ethanol fuel is limited due to the lack of E85 refuelling infrastructure. Flex-fuel vehicles are common in the Midwest, where corn is a major crop and is the primary feedstock for ethanol fuel production. Besides, the U.S. government has also been using flex-fuel vehicles for many years.



Alternatives to Ethanol – Methanol and Electric Vehicles

Methanol

Methanol occupies a critical position in the chemical industry, as a highly versatile building block for the manufacture of countless everyday products such as paints, carpeting, plastics and more. Increasingly, Methanol is being viewed as a clean and sustainable fuel rather than just a petrochemical. It has inherent clean-burning properties which produces lower emissions upon combustion in a land/marine vehicle.

Methanol can be produced from any carbon source such as natural gas, coal and biomass. Natural gas is the most popular feedstock to produce methanol. Globally coal to methanol is a proven technology. India being the 5th largest country with coal reserves, it is advisable to trap its large coal reserves to produce methanol. However, fuel applications for methanol have been relatively minor historically with very limited direct use as a motor fuel.

IOC has currently undertaken pilot roll out of M15 fuel in Digboi Assam.

Global Scenario

China has emerged as the dominant country with respect to both methanol capacity and demand owing to its rapid economic growth. China represented 12% of global methanol demand in 2000 while the consumption has grown to 54% of global demand in 2015. Chinese direct blending use of methanol into the country's gasoline pool has seen an average annual growth rate of 25% from 2000 to 2015, resulting in gasoline blending becoming the third largest demand segment for methanol by 2015.

Challenges

There are certain challenges in adoption of methanol as a fuel, some of these being:

- Vehicle Availability - Vehicle manufacturers are yet to approve the fuel for their vehicles.
- Price Disadvantage - in case of energy equivalence, M15 calorific value is 7.5% less than normal Gasoline.
- Material Compatibility – Due to its corrosive nature, large numbers of materials such as Neoprene are not compatible with M15. In case of further Roll out, M15 compatible Dispensing units need to be procured.
- Toxicity - Methanol is a toxin; ingestion of a small amount (around 30 to 60 ml) may cause death. Breathing vapour and contact to skin are also dangerous. Handling the product requires proper training.
- Customer Acceptability.

Notwithstanding the above challenges, Methanol blending with Gasoline will dent the demand number for Ethanol requirement in the future to come, if it materializes.

Electric Vehicles (Evs)

The push for Electric Vehicles (EVs) is driven by the global climate agenda established under the Paris Agreement to reduce carbon emissions in order to limit global warming. The transition to electric mobility is a promising global strategy for decarbonising the transport sector. Falling battery costs and rising performance efficiencies are also fueling the demand for EVs globally.

India is in need of a transportation revolution. India is among a handful of countries that support the global EV30@30 campaign, which aims for at least 30% new vehicle sales to be electric by 2030.

The Government of India has taken various measures to develop and promote the EV ecosystem in the country such as the remodeled Faster Adoption and Manufacturing of Electric Vehicles (FAME II) scheme, Production-Linked Incentive (PLI) scheme for Advanced Chemistry Cell

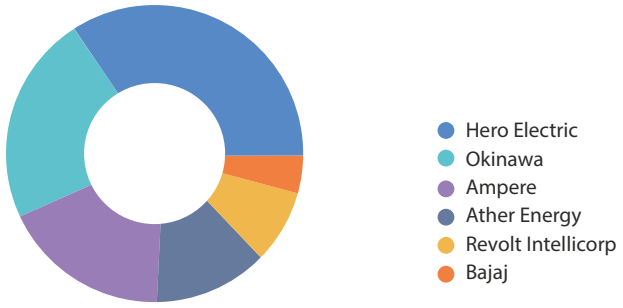
India is among a handful of countries that support the global EV30@30 campaign, which aims for at least 30% new vehicle sales to be electric by 2030.

(ACC) for the supplier side and the recently launched PLI scheme for Auto and Automotive Components for manufacturers of electric vehicles.

According to Govt of India's Vahan Dashborad, in 2020, as the Pandemic restricted mobility, EV registrations shrank 26% to 119,656 vehicles. But when the economy rebounded, so did EVs. In 2021, India has registered 260,436 EVs till November.

Evs will contribute to improving the overall energy security situation as the country imports over 80% of its overall crude oil requirements, amounting to approximately $100 billion. The push for EVs is also expected to play an important role in the local EV manufacturing industry for job creation.

India Electric Two Wheeler Market - Revenue Share (%), By Manufacturers, 2020



Source: Statista.

Alcohol to Jet (ATJ) Fuel

The aviation industry is critical to the country's economic development. Its expansion however has an environmental consequence as it releases greenhouse gases into the atmosphere at high elevations. According to the International Air Transport Association (IATA), the worldwide aviation sector produces around 2-3 % of global CO2 emissions[1].

Globally, industries and policymakers are looking at reducing carbon emissions, specifically from the international aviation sector and the international shipping industry, as they were not covered under the Conference of Parties-21 (COP-21). The Paris Agreement is a legally binding international treaty on climate change. It was adopted by 196 Parties at COP 21 in Paris on 12 December 2015. Its goal is to limit global warming to well below 2 degrees Celsius, preferably to 1.5 degrees Celsius, compared to pre-industrial levels (1850–1900).

COP-26 Declaration – International Aviation Climate Ambition Coalition[2]

The state representatives, participating in the inaugural meeting of the International Aviation Climate Ambition Coalition at the 26th Conference of the Parties (COP26), in Glasgow on 10 November 2021, signed a declaration covering enlisted major aspects. The Conference recognized international aviation's material contribution to climate change through its CO2 emissions and emphasized upon the need to align international efforts to reduce emissions from the aviation sector with a pathway towards achieving the temperature limit, as specified in Paris Agreement. It acknowledged ICAO (International Civil Aviation Organization) as the appropriate forum to address emissions from international aviation through in-sector and out-of-sector measures to implement short-, medium- and long-term goals, including the development of a global sustainability framework to support the deployment of sustainable aviation fuel (SAF) and the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA).

'CORSIA' as an emission mitigating measure

ICAO has adopted a market-based measure, Carbon Offsetting Reduction Scheme for International Aviation (CORSIA), under which aircraft operators would be required to purchase and cancel "emissions units" to offset any increase in CO2 emissions above a 2019 baseline. CORSIA is an emission mitigation approach for the global airline industry, developed by ICAO (International Civil Aviation Organisation). CORSIA addresses emissions only from international air travel. The main aim of CORSIA is to reduce aviation net CO2 emissions to 50% of 2005 levels by 2050. India is not participating in the voluntary phase of CORSIA but would have to participate mandatorily in the second phase, starting from 2027.

The Indian aviation industry has three options to meet the requirement

- Buy CORSIA-approved carbon offset credits to meet carbon emissions offsetting requirement
- Buy Sustainable Aviation Fuel (SAF) fuel internationally, which may be available at higher costs
- Buy SAF fuel produced in India preferably using Indigenous technology

Based on India's ATF consumption (8.3 MMTPA in 2018-19) and a 10% SAF fuel blend in conventional ATF, 0.83 MMTPA of SAF fuel is required, resulting in a foreign exchange savings of Rs 160 billion per year when compared to importing SAF at current global prices of around 200 Rs/kg (exclusive of duties and taxes).

1 https://www.iata.org/en/programs/environment/climate-change/
2 https://www.gov.uk/government/publications/cop-26-declaration-international-aviation-climate-ambition-coalition/cop-26-declaration-international-aviation-climate-ambition-coalition#signatories

Moreover, producing SAF domestically can be one of the options and Alcohol to Jet fuel can be produced from Agricultural Residues and Surplus Sugar Streams. Thus surplus Ethanol in future can be diverted to SAF production domestically. Government push on E20 blending will lead to surplus Ethanol availability as many dedicated ethanol plants are in the pipeline to be put by prospective bidders in each state. Thus BOLT on facilities can be done with any existing ethanol plant for Alcohol to Jet fuel (SAF) production, and the SAF can be mixed upto 50% with fossil-based ATF fuels. India can be a global hub for SAF for other international flights and thus can leverage the ATF business to its advantage. All the airlines will be required to use SAF for CORSIA mandate.

Challenges in India's Ethanol Industry

Ethanol blending of petrol is not only a national imperative but also an important strategic requirement. The government is making various efforts to put in place a favourable regulatory and retail ecosystem for safe and effective use of ethanol-blended petrol.

However, there are various challenges being faced in the ethanol industry at various ends, to maintain sustained supplies, some of which are discussed below:

Based on India's ATF consumption (8.3 MMTPA in 2018-19) and a 10% SAF fuel blend in conventional ATF, 0.83 MMTPA of SAF fuel is required, resulting in a foreign exchange savings of Rs 160 billion per year.

- **Less Production:** Currently, domestic production of bio-ethanol is not sufficient to meet the demand for ethanol for blending with petrol at Indian OMCs. Sugar mills are the key domestic suppliers of bio-ethanol and currently they supply around 55-60% of the total demand. But there are certain limitations with them. For instance, sugar mills do not have the financial stability to invest in biofuel plants and these mills are heavily concentrated on certain regions – i.e. UP, Maharashtra and Karnataka.
- **Inter-state Movement of Ethanol:** The central government amended the Industries Development and Regulations Act to ensure smooth implementation and transportation of Ethanol across the country. However, same has not been implemented in all states.
- **Non-uniform Availability:** Ethanol is not produced or sufficiently available in some states for ethanol blending. Major Ethanol deficit states include Tamil Nadu, Kerala, Odisha, West Bengal, Rajasthan, Madhya Pradesh, Chhattisgarh, Gujarat and the North Eastern states.

  The transport of ethanol to different places for blending increases the cost of logistics and transport-related emissions.

Ethanol being an environment-friendly fuel will help India meet carbon emission reduction goal. It will boost rural economy, improve farmers' income and create jobs in rural areas and lower India's import dependency.

  However OMCs have come up with multimodal transport solution to position Ethanol in every nook and corner of the country. Currently Ethanol is being transported through product pipeline and Rail, in addition to existing road mode. IOC has started EBMS pumping on Mathura -Tikri Pipeline as well as Panipat-Rewari Line and has the plan to start EBMS pumping in other product pipelines. Al the OMCs have started EBMS loading through rakes (Railway tank wagon) from Mathura to Jammu in the first phase and other locations subsequently. Similarly HPC has stared pure Ethanol loading from Pune to Kadappa.
- **Challenges to Vehicle Manufacturers:** Even though vehicles made in India are material compatible with E10 and compliant with E5 with regard to fuel efficiency since 2008, there are certain inherent challenges. For instance, with the proposed target of E20, the vehicles are now required to become both materials compatible and fuel-efficiency compatible for E20 fuel. The cost of E20 compatible vehicles is expected to be higher.

The Way Forward

Given the strategic importance of Ethanol blending, the challenges discussed above need to be addressed at the earliest possible. Some of the strategies for addressing the challenges and meeting the objectives envisaged in the National Biofuels Policy include the following:

- **Augmenting Ethanol Producing Capacity:** According to NITI Aayog, to achieve 20% ethanol blending, India has to augment both the sugarcane-based and grain-based ethanol production capacities by 78% and 187% respectively. OMCs have come up with expression of interest (EOI) for entering with Bi-partite agreement for putting up of Dedicated Ethanol Units (DEU) in Ethanol deficit states.
- **Uniform Availability of Ethanol Blends:** All the states have to implement the amended Industries Development and Regulations Act for facilitating the Inter-state movement of ethanol from Ethanol surplus states to Ethanol deficit sates for blending uniformly Pan-India.

- **Suggestions for Vehicle Manufacturers:** Once India achieves E20, the government may push towards E-85 fuel (85% ethanol by volume), E100 [pure ethanol] and may explore 5% blending in Ethanol in Diesel subject to necessary specification (BIS) development /OEM approval etc. The vehicle manufacturers have to produce equipment that are future-ready, including introduction of flexi-fuel vehicles.
- **Pricing of Ethanol Blended Petrol:** For better acceptability of higher ethanol blends in the country, the retail price of blended petrol should be lower than normal petrol. Thus, tax benefits may be extended on Ethanol Blended Petrol.
- Faster environmental clearances to upcoming distilleries

India can learn from Brazil on successful implementation of flexi vehicles, and cultivation of energy cane for higher production over same acreage of land. Ethanol being an environment-friendly fuel will help India meet carbon emission reduction goal. It will boost rural economy, improve farmers' income and create jobs in rural areas and lower India's import dependency. With Government support, the Ethanol Blending Programme will be successful and can meet the target of 20% blending by 2025. India's net import of petroleum was 212 Mt at a cost of US $119 billion in 2020-21. Most of the petroleum products are used in transportation. Hence, a successful E20 program can save the country US $4 billion per annum, i.e. Rs. 30,000 crore. The other use of Ethanol feedstocks can be for SAF production to comply with CORSIA mandate as well to take the Bio-ATF program (through ATJ route) forward in India.

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References:

a) Gazette Notification on Biofuels dated 5th Feb-2019

b) National Policy on Biofuels – 2018: Gazette Notification dated 04th June 2018

c) Expert Committee Report on "Roadmap for Ethanol Blending in India: 2020-2025" by Niti Aayog & MOPNG

d) Cars and light trucks: ANFAVEA (2003-2017)

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e) https://www.statista.com/ statistics/ 712070/ number-of-registered-automobiles-in-brazil/

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h) OMCs Ethanol Blending performance

i) MOPNG Circulars on Pricing / OMCs EOI -ESY Wise

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Rajesh K Mediratta
MD & CEO, Indian Gas Exchange Ltd

Rajesh Kumar Mediratta has over three decade of experience in power and gas sector and played key role in commencing first electricity and gas exchanges in the country. He was key founder member of the team for establishing first power exchange the country in 2007 and gas exchange in 2019. Before IEX & IGX, he worked with apex electricity planning body Central Electricity Authority, Power Grid Corporation in the areas of system operation and commercial settlements. His current interests are in Energy transition, decarbonisation, gas and power markets. He has to his credit several papers on gas, power markets, renewable markets, commercial mechanism, power system operation and settlement systems and on reforms in gas and power sector, presented at international and national conferences. Mr. Mediratta holds a bachelor's degree of mechanical engineering (Gold Medallist) and MBA in Finance. He is currently holding the position of MD&CEO at IGX

The Natural Gas Economy in India – Transitioning to a New Dawn

Natural Gas can meet India's growing demand for clean and affordable energy by replacing coal and oil and their associated higher carbon emissions. This is possible with proactive and sustained policy support from the government and regulatory agencies.

India is the 3rd largest energy consumer in the world which primarily relies on high carbon emitting fuels like coal and oil to meet it growing energy demands. Presently, share of Natural Gas in India's total primary energy consumption is 6.3% as compared to world's average of 24.2%. Natural gas is an environment-friendly fuel and a compelling alternative to dirtier fuels, and hence can play a critical role in reorienting India towards a low carbon economy. Natural Gas can meet India's growing demand for clean and affordable energy by replacing coal and oil and their associated higher carbon emissions.

Countries such as USA, UK, EU, Australia, etc. have well-developed and vibrant gas markets with significant gas use in major sectors of their economies owing to sustained periods of high economic growth coupled with tough environmental and air quality control laws. These developments led to rapid expansion of gas pipelines and local gas distribution networks in these countries to cover all their geographical areas. Such economic transformation would not have been possible without proactive and sustained policy support from these countries' governments and regulatory agencies.

In India too, the Government aims to:

i. Reduce emissions by having emission intensity target of 45% by 2030 below 2005 levels;

ii. Transform India into a gas-based economy by increasing the share of Natural Gas in India's primary energy mix to 15% by 2030.

India is a price sensitive market and is moving towards the stated objective of achieving a gas-based economy. Development of domestic gas sources through exploration and production activities are aimed at increasing the domestic gas production by about 50 Million Metric Standard Cubic Meter per Day (MMSCMD) by FY 2023-24.

Government initiatives are beneficial to the natural gas industry because they aim to:

i. Reduce emissions by having emission intensity target of 45% by 2030 below 2005 levels;

ii. Transform India into a gas-based economy by increasing the share of Natural Gas in India's primary energy mix to 15% by 2030.

In FY 2021-22, India consumed nearly 160 MMSCMD of Natural Gas and achieving 15% of Natural Gas in the primary energy mix would entail increasing the gas consumption to over 500 MMSCMD. Currently, around 75 MMSCMD or nearly 47% of total Natural Gas consumption is met by domestic production and the rest through imports in form of liquefied natural gas (LNG).

The country has 6 LNG terminals that are located in Dahej, Hazira, Dabhol, Kochi, Ennore and Mundra with total LNG regassification capacity of around 42.5 MMTPA. Development of additional ~25 MMTPA LNG Regassification facilities on both east and west coasts of India like Chhara and Jafrabad in Gujarat; Dhamra in Odisha; Krishnapatnam and Kakinada in Andhra Pradesh will bring the total LNG regassification capacity of India to around 70 MMTPA in next 3 years. The setting up of terminals on both east coast and west cost will lead to development of gas supply sources particularly in the eastern part of country.

The completion of "One Nation, One Gas Grid" or Natural Gas pipeline infrastructure is crucial to improve Natural Gas access to newer geographic areas of India. About 15,000 km of additional lines are currently in various stages of completion. This includes the much-delayed Kochi - Koottanad - Mangaluru - Bengaluru pipeline (KKMBPL) and the Jagdishpur - Haldia - Bokaro - Dhamra Pipeline (JHBDPL or Urja Ganga) pipeline which will connect virgin areas in the Southern and Eastern India to the national gas grid. Further, the Indradhansuh Gas Grid is expected to connect the North-Eastern states in India by 2024. This would bring additional domestic gas from the gas fields in that region to the National Gas Grid. Once completed the total pipeline network will be nearly 35,000 KMs.

India's gas consumption is largely driven by fertilizer plants, city gas networks, refineries, petrochemical, steel and power plants. India is connecting previously unconnected Refineries, Petrochemical and Fertiliser plants which were using Naphtha to gas infrastructure to increase utilisation of Natural Gas in the country.

The Petroleum and Natural Gas Regulatory Board (PNGRB) has conducted 11 bidding rounds along with the recent 11 (a) bidding round till date for award of licenses to entities to set up city gas distribution (CGD) infrastructure in the authorized geographical areas (Gas). The 11th round received participation for 61 GAs out of the 65 GAs on offer and PNGRB issued Letter of Intents to successful bidders with regard to 52 out of 61 GAs. 11 CGD bidding rounds cover almost 86% of Indian geographical area and 96% population and in the 11

(a) round, additional 5 GAs were allocated. This will lead to rapid expansion of CGD network in the next 6-8 years, thus increasing Natural Gas usage in the country.

These CGD projects can be given a push start by introducing the small-scale LNG (ssLNG) as a plug and play arrangement for rapid development of the GAs where the pipeline connectivity is not available. Existing LNG terminals are adding road tanker loading bays to meet the growing demand of ssLNG. In FY 2021-22, approximately 1,30,000 MT of LNG was supplied via ssLNG and this demand will further increase as the usage of LNG increases in Bunkering fuel for ships/ barges/ fishing vessels on Inland waterways; ISO LNG tank containers for supply of LNG by road, rail and sea routes to nearby countries / islands and in mining vehicles.

Dedicated LNG corridors for use as a fuel for transportation are being planned especially along the Golden quadrilateral highway which connects Delhi – Mumbai – Bengaluru- Kolkata to replace diesel vehicles. 50 LNG dispensing stations have been proposed to be set up by end of FY 2022-23, with additional 600 stations to be completed by end of FY 2025-26 from entities like IOCL, BPCL, HPCL, PLL, IGL and GAIL etc. OEMs like TATA Motors, Volvo-Eicher and Ashok Leyland will also be launching LNG-fueled vehicles by FY 2022-23. Diesel vehicles switching over to LNG can help reduce carbon footprint and it is estimated to be 10-15% more economical compared to diesel.

Under "SATAT – Sustainable Alternative Towards Affordable Transportation" scheme, there are plans to set up about 5,000 Compressed Bio-Gas plants. Currently, 28 plants have been commissioned and approximately 5,300 tonnes of compressed Biogas (CBG) have been sold till March 2022. Easy financing for renewal of Natural Gas projects from Government of India and the recent revision in rates for the offtake of CBG at par with CNG retail selling price is another incentive for entrepreneurs across the country to set up more CBG plants.

On the policy front, India's first Gas Exchange, Indian Gas Exchange (IGX) was launched for creating a competitive spot market ecosystem in India. The policy directive issued by Government of India to regulator PNGRB expected the Gas Exchange to: (i) secure equitable distribution, and (ii) increase availability of gas by creating a free market to usher in a gas-based economy. It serves the important role of providing gas buyers and sellers easy market access, informed price signals, flexible procurement terms, as well as a secure and transparent payment system.

Recently, the domestic gas producers who have pricing and marketing freedom have been allowed to sell upto higher of 500 MMSCM or 10% of their annual production per year through authorized Gas Exchange(s).

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That being said, there is still a long way to go in order to quickly transition into a gas-based economy efficiently. More policy enablers are needed to achieve a vibrant gas-based economy and bring more liquidity on gas Exchange.

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The unbundling of the transmission and marketing of gas is an urgent requirement. Bundled gas contracts coupled with destination inflexibility in gas contracts restrict the growth of gas market in the country. Further, the transportation of gas must not be in the hands of the same entities that sell the gas if a transparent and unbiased market is to be fostered which allows for equal and fair access to all parties concerned. The government has taken note of this and the process for the setting up of a Transmission System Operator (TSO) has already begun. This TSO will be entrusted to maintain and operate the gas infrastructure and will be completely separated from any trading or marketing activities. In addition to allowing equal access to these pipelines for third parties, it also frees up useful CAPEX that can be solely utilized to further grow new infrastructure and maintain the existing ones, instead of having to be divided and allocated towards other activities like marketing. In addition to bringing transparency and reducing the possibility of the creation of a monopoly, the TSO will also facilitate appropriate tariff rates by virtue of stimulating healthy competition amongst the players.

Issues related to non-uniform taxation remain a longstanding concern of the gas industry and affects the growth of gas markets. The current non-uniform taxation structure is a hinderance to the development of "one-nation-one-market".

Implementation of Unified Transmission Tariff will significantly enhance the competitive sourcing of Natural Gas from multiple gas hubs/delivery points and will alleviate pancaking effect of tariffs if multiple gas pipelines are involved.

Declaration of CGD network as common carrier whose marketing exclusivity has expired will increase buyer competitiveness by enabling them to purchase from third party gas supplier. This step is yet to be fully implemented, even though PNGRB issued public notices, inviting comments on declaration of 54 Geographical Areas as Common Carrier/ Contract Carrier. If consumers located on the CGD are allowed to source their gas as per their own requirements from producers of their choice, this competitive market can get even deeper.

All these measures will attract more participants into the gas sector which will increase investments and thereby increase liquidity of the natural Gas market. Once this happens, a robust competitive market will emerge, which will benefit consumers with better service and lower tariffs.

The Indian energy sector is in the cusp of the great transition to clean, eco-friendly based ecosystem. In this context, the series of investments across the gas value chain to enhance the share of Natural Gas and move towards a gas-based economy will also lay the groundwork for a low emission Indian economy.