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Creating Innovative Solutions for a Sustainable Future

KONRAD ADENAUER STIFTUNG

India's Role in Global Energy Governance Framework: 2040 and Beyond

Editors
Swati Ganeshan • Souvik Bhattacharjya

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FOREWORD

We are in the middle of a planetary climate emergency. Already today, the 1% increase in our global average temperature compared to pre-industrial levels negatively impacts our water supplies, biodiversity, marine ecosystems and food production, as well as causes dramatic climate hazardous events. Events such as the devastating floods in my home country Germany some months ago are proof that climate protection has become the need of the hour, whose ultimate success hinges on triggering a global transition towards green energy solutions.

This goal and its emergent nature is beyond contestation now and India, as one of the highest energy consuming countries, largely sparked by the astonishing number of around 700 million Indians gaining access to electricity between 2000 and 2018, stands at the forefront of the quest for innovative, durable and sustainable green energy solutions to meet its ever-increasing energy demand.

In the recent past, Indian decision-makers have taken impressive strides to ensure that the subcontinent will attain a self-sufficient, self-determined and clean energy future with India's initiative of the "International Solar Alliance" (ISA) comprising 121 countries being a salient case to the point. Given that the climate crisis poses a global threat, it is only through such multilateral organizations and cooperation that we will find valid ways to implement environment-friendly energy technology globally and thereby tackle the climate crisis head on.

In this regard, enhanced cooperation in the areas of research and innovation is also of vital importance. Hereby, joint problem-solving endeavours, such as the India-EU partnership on "Building a low-carbon, climate-resilient future" under the EU's "Horizon 2020" framework programme, represent important initial stepping stones on the long journey towards a carbon-neutral transformation of our economies. Divisive elements such as the competition for technology and innovation spaces as well as resources must be resisted, as the only possible approach to attain our 1.5 Celsius climate goal lies in the worldwide exchange of modern technologies and know-how in the realm of clean energy development.

Moreover, with energy lying at the very core of every nation's economic performance, achieving the European Union's and indeed also India's cross-cutting aim of becoming climate neutral by 2050 whilst not hampering development, prosperity and security will necessitate tailor-made, science-based and multilateral policymaking approaches.

It is in the light of this fact that the role and relevance of publications such as the present one becomes apparent. I cast not the slightest shadow of doubt that it will serve as a blueprint for sustainable solutions to global energy challenges as well as a toolkit for climate action towards a safer and greener future.

Furthermore, I am extremely satisfied that our long-standing cooperation of nearly two decades with TERI has resulted in yet another milestone publication wherein it has been highlighted that all parts of our societies, from large companies to think thanks and the civil society, have a moral obligation to actively advocate for a greener planet. Positive changes will only be achieved if the majority of the world's population vigorously demands for and supports such transformations. In this respect, this publication fills another crucial lacuna by raising public awareness of the challenges of climate change as well as its feasible solutions.

There still remains much to be done globally for a green energy future it is only by joining our forces that we will be able to overcome the current challenges posed by climate change and ensure a better tomorrow for our generations to come.

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The book has been a culmination of joint efforts and initiative by Konrad-Adenauer-Stiftung India Office and The Energy and Resources Institute (TERI), New Delhi. The focus of the publication was to bring together academicians, policymakers and thinkers on energy security, to discuss the new paradigms, perspectives and approaches that are shaping the global energy discourse. We are immensely thankful to our partner KAS India for providing us the opportunity to develop this publication.

We are indeed grateful to all the distinguished speakers who participated in our diginars and national workshop for their insights, suggestions, reviews and comments that aided and enhanced our understanding of energy security and how it has transformed over the years from a purely geopolitical and fossil fuel-based narrative to a more expanded discussion on social, economic, technological, cultural and political factors that are interspersed and interdependent within the energy domain.

We would like to thank Mr Peter Rimmele, Resident Representative KAS India and Mr Pankaj Madan, KAS India for their unwavering support, inputs and guidance for the overall initiative and the publication.

We would like to thank esteemed colleagues Simran Dhingra and Ashish Gupta at KAS; John Andruse, M K Bineesan, Kartikeya Sharma and TERI Press at TERI for their continued support throughout the initiative. A big thank you to Dr Vibha Dhawan, DG, TERI for providing organizational support for the project. We would also like to thank all the authors for contributing interesting and informative papers that will surely add value to the discourse.

As the editors of this publication, we are extremely privileged and honoured to have been able to learn from distinguished experts and contributing authors. It has been a rewarding and valuable learning experience to undertake the initiative and develop this publication.

Editors

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INTRODUCTION

Redefining Energy Security in India—Transformative, Inclusive and Evolving Future

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Introduction

India's energy profile has been at the focal point of global climate discussions with increasing expectations to reduce GHG emissions, acceleration of renewable energy deployment, augmenting sustainable practices and fulfilling its SDGs commitments within a stipulated time period. With a total emission of more than 2.3 billion tonnes (with a share of 7%), India is third largest emitter after China and United States. Nearly 70% of the total CO2 emission is attributed because of coal combustion (IEA-2021). As per the ministry of coal (MoC, 2020) India's overall coal consumption was reported at 955.307 million tonnes (mt) for the 2019-2020. Further 70% of the coal was used for power generation, while 30% finding application in non-electricity sectors including steel, cement, and others.

While the call to reduce dependence on fossil fuels have been there for quite sometime, the recent release of the findings of AR (6) that predicted the potential threats of increased heat waves, longer warm seasons, and shorter cold seasons across major regions of the world, led to a call on aggressive decarbonization strategies. With several countries such as EU pledging to transform into carbon neutral societies by mid of 21st century, there were expectations from India to make further deliberations and commitments on climate goals. The recent announcement by India at the CoP 26 on setting a net zero target by 2070 and agreeing to phase down of coal with substantially increasing the share of the renewables in the energy mix by 2030 has been a welcome move. This is also the first time that coal has been explicitly mentioned in any COP meeting decision.

Even before the world began to witness the implications of the COVID19 induced pandemic on the energy mix and systems worldwide, globally the power sector is in the middle of a transformational process. Despite fossil fuels usage to generate a large chunk of the power in most of the countries globally, renewable energy based power sources such as solar, wind and hydro are dominating the growth of global power generation (Bertram et al., 2021). The situation is no different for India as well. In India the utilisation of coal-fired power plants fell from over 70% in 2010 to 55% in 2019, and the pandemic caused a further fall to below 55% (IEA, 2021). The pandemic also reduced the demand for power sector due to the disruption in the functioning of energy intensive sectors, however with resuming of industrial sectors, the momentum would accelerate in post pandemic situation. Fossil fuels were partly squeezed out of the electricity generation mix in 2020 and global CO_2 emissions from the power sector decreased around 7%. In India, the USA, and European countries alone, a more dramatic picture has emerged over the last year or so, as in the aforementioned key markets monthly electricity demand has declined by up to 20% as compared to 2019 while the monthly CO_2 emissions have also decreased by up to 50% (Bertram *et al*., 2021).

The discussion on energy is being steered and influenced by NDC commitments and associated actions. Increasing momentum towards energy and resource efficiency in Industrial and other sectors are transforming energy design, planning and implementation. With increasing impetus to increase energy and resource efficiency, reduce emissions and ensure minimal wastage- the road to energy security in India has transformed into complex framework where the role of geopolitics is significant but not the primary concern.

The rationale for internationalization and international cooperation on energy security for a country is based on economic interdependencies concerning energy related technology, fuels and trade involved therein. Like other countries, India is also reliant not only on traditional energy sources but also cleaner sources of energy and dependent on imports for energy related raw materials.

India's Achievements so far and Challenges

Energy security has become complex, layered and multidimensional subject with deep rooted linkages to evolution of International and National climate policies. Being energy secure has transcended from ensuring access to resources to conserving, preserving and ensuring efficient usage of energy resources. As economics play a significant role in energy security, the scales have tipped towards accelerating renewable energy resources that are affordable (low costs of procurement), clean (reduce emissions), available (reduced geopolitical uncertainties and accessible (ease of deployment). India has been walking this path vigorously in the recent years, however some key questions that arise is how do other energy sources that are still vital in the energy mix adapt to this rapid transformation and what are the major impediments and challenges for renewable energy sector in India and how are transformations in energy allied sectors changing the way energy should be generated, operated and delivered. Yet there are challenges in encountered in enhanced deployment of renewable energy in the country. India has manufacturing sector for Wind energy, yet the rate of installation has been indeterminate with projects being delayed or cancelled and new auctions being undersubscribed due to long gestation periods in grid augmentation, land acquisition and location of the site play a crucial role in advancement of wind energy sector. India's Solar sector has registered fastest deployment in recent years with several projects being implemented at a rapid scale. Though India has accelerated its solar implementation and has ventured into technological collaborations leading to recent success in floating solar projects in the country, the lack of solar cell and module manufacturing still hinders its overall portfolio and economic development. Existing solar manufacturers lack the technological skill to participate in government tenders as they are unable to fulfill the technical requirements stated under it. Further, Indian solar cells are, on average, 20-30% more expensive than cells manufactured in China (Prasad, 2020).

Nonetheless collaboration has been working on developing disruptive technologies through foundational research in sustainable photovoltaics (PV), multi-scale concentrating solar power (CSP) and coupled to an analysis activity to address the critical barriers for solar energy (Ginley et al., 2018). In addition, this growth will be accompanied by the increasing presence of distributed energy resources (DER) such as roof-top solar (RTS), electric vehicle (EV) charging and other behind-the-meter technologies for energy storage and control of energy consumption by consumers.

Technologically infused battery collaborations at a global level still remains an unexplored segment for India as it hasn't forged any intellectual alliances for its development. There exist several interdependencies between clean energy technologies like solar, winde and electric vehicles, at the base of their long terms sustenance is the marketability and evolutions of energy storage batteries. The success of battery technology is critical to the development of India's clean energy initiatives as it seeks to expand its solar energy deployment and transform its fossil fuel based transportation fleet into an electric one. Although India has forged alliances with Bolivia and Argentina to access their lithium reserves (Mishra, 2019; Siddiqui, 2020), the lack of technological development on that front will make battery ownership too expensive for any form of large scale deployment.

In the nuclear energy space, India has a combined capacity of 6780 MW in operation in the country and nine) reactors, with a total capacity of 6700 MW about 3% of total electricity capacity is under construction (MOAE 2020a). India's nuclear power share in its energy mix has remained constant with marginal increases. The sector has faced challenges with regard to public perception about safety and security concerns. International regulations and monitoring of civil nuclear energy establishment is significant aspect that permeates into the domestic nuclear establishment, however even with high safety standards nuclear has remained dormant in India's energy mix due to several international historical incidents such as Fukushima and Chernobyl. India's nuclear energy share hasn't increased for several years even though the sector has been identified as a key pillar for fulfilling its NDC commitments.

Though Indian nuclear energy sector still remains significant due to its strategic nature, the perception around the resource has strong resonance in policy making. The nuclear energy sector is an excellent example of indigenous technological innovations and developing entire supply chains. Innovation and technology developments in this sector have paved the path for advancements in several sectors. There is a need for India enhance its technological prowess and the nuclear energy sector could be the answer to initiating and developing disruptive technologies.

India's energy sector structure is dependent on the international commitments adopted by India under the UNFCCC and SDGs. India has set an eight point ambitious target as part of its National Determined Contributions. India is party to the Kyoto Protocol and the Paris agreement and remains an active participant in international climate and sustainability dialogue.

India has aggressively pursued its NDC commitments under the Paris Agreement and has achieved a reduction in emission intensity of GDP by 21% over the period 2005-2014 (Jaiswal, Joshi 2019). Brown to green report 2019 by Climate transparency has highlighted that India is close to being in line with achieving its emissions target with a 1.5°C world. This is a strong evidence of India's progress in SDGs as well.

India recently released the second edition of the SDG dashboard highlighting the progress that India has achieved as a whole and the State level. According to the SDG Index and Dashboard 2.0 of Niti Aayog released in 2019, "The composite score for India improved, from 57 in 2018 to 60 in 2019. The country overall has progressed towards achieving the SDGs. Five goals drive the positive push – 6 (clean water and sanitation), 7 (affordable and clean energy), 9 (industry, innovation, and infrastructure), 15 (life on land), and 16 (peace, justice, and strong institutions), where India has scored between 65 and 99. Two goals – 2 (zero hunger) and 5 (gender equality) demand special attention, as the overall country score is below 50 (NitiAayog 2019).

The dashboard is a positive step towards reviewing the progress in SDGs'; however India has a long way to go. Additionally, the dashboard has many gaps due to inadequate data for many goals; this is also a challenge that needs to be addressed urgently. The global success of achieving SDGs by 2030 primarily depends on the progress that is made by countries like India and China that account for the largest populations and an increasing share in the global economy. India can achieve its SDG goals by 2030 only if the States achieve their SDG goals. This is particularly necessary in the case of large States such as Uttar Pradesh, Bihar, and Madhya Pradesh. In context to energy, this is particularly relevant at the level of electricity /power sector, where in DISCOMS are state led. Additionally, energy sector also depends on various other variables such as tariffs that are largely set by state governments, all of this have a cumulative bearing on India's domestic energy structure. India has moved ahead in SDG 7, however there are many other goals that are directly or indirectly dependent on energy for fulfilling their targets related to transport, infrastructure, agriculture, health and poverty.

India faces a complex set of challenges in the context of framing of policies relating to the SDGs at national level that provide a scope for state level and local level interventions, engagement and participation. In a vast and diverse country with a federal structure, the process of implementing the SDGs needs extensive and multi-layered implementation mechanisms. The diversity makes it necessary to ensure that local contexts are taken adequately into consideration, both in conceptualizing the problem and in finding the solutions. In context to energy, the role of energy in health and social welfare services needs to be internalized in local level implementation.

The Key Drivers to a Cleaner India

Technological innovation is the key constituent required to mitigate the growing impact of climate change, given that climate change has disproportionately impacted developing countries more than the developed nations. The notion of technology transfer is mentioned in the article 4 of UNFCCC's commitments section, where the convention elaborates on the need for financial assistance and technology transfers from developed to developing countries to prevent the growth of anthropogenic emissions of greenhouse gases.

Countries across the world have also began to accelerate their efforts to decarbonize the environment; in India the The NITI Ayog and the International Transport Forum (ITF) of Organization for Economic Co-operation and Development (OECD), have jointly launched a project aimed at decarbonizing India's transport sector in early 2020. The project is aimed to develop a pathway towards a low-carbon transport system through new modeling tools and policy scenarios. The project will design a tailor-made transport emissions assessment framework for India (Parikh, 2020). Further, if we look at trends across from the world, in 2020, global investment in the low-carbon energy transition totaled $501.3 billion, up from $458.6 billion in 2019 and just $235.4 billion in 2010. The largest sector in 2020 was renewable energy, which attracted $303.5 billion for new projects and small-scale systems. This was up 2% on 2019, despite COVID-related delays to some deals (BloombergNEF, 2021).

Further, from a technological standpoint the world is rapidly taking notice of CCUS (Carbon Capture Utilization and Storage) technologies as plans for more than 30 new integrated CCUS facilities have been announced since 2017 across the world. The vast majority of these projects are in the United States and Europe, but projects are also planned in Australia, China, Korea, the Middle East and New Zealand. If all these projects were to proceed, the amount of global CO_2 capture capacity would be more than triple, to around 130 Mt per year (IEA, 2020). India is also strategically diversifying itself within the CCUS gambit. The country's Department of Science and Technology has established a national programme on CO_2 storage research and, in August 2020, made a call for proposals to support CCS research, development, pilot and demonstration projects. This is part of the accelerating CCS technologies (ACT) initiative, for which India has committed one million euros to support Indian participants. At least 16 countries, regions and provinces are working together in ACT to fund research and development that can lead to a safe and cost-effective CCUS technology (Trivedi, 2020).

During the Union Budget for 2021-22, India announced a National Hydrogen Energy Mission (NHM) that would focus on setting a roadmap for Hydrogen as an energy source. This step would be significant for the transportation sector. The goals is to shift to green hydrogen from gray hydrogen eventually. India intends to link the renewable energy capacity to the hydrogen economy to address the dual challenge of reducing emissions and reducing import dependency. While the economic sustainability of the extraction of hydrogen needs to be examined, however the announcement of the mission highlights the importance provided to this source for future use in India.

It has been founded that given India's compliance with various multilateral organizations on the aspect of climate change, it needs an estimated $2.5 trillion from various international and domestic sources to meet its targets by 2030 (IGP, 2015). According to the Global Landscape of Climate Finance 2015 more than 74 percent of climate finance originating in developed nations in the year 2015, was invested domestically. This needed to change especially since going into Paris for COP21, developing nations were vocal about needing significant support in terms of finance and technology to achieve climate targets that the international community was pushing hard (Buchner et al., 2018). One of the primal vision for climate funding in the current scenario is the need for better global coordination and oversight of funding for climate research. A coordination failure in such a scenario can lead to overlaps in research areas while ignoring other imperative areas completely. This was largely seen in feminist literature where for the longest time due to lack of considerable funding options there was little information available on how climate change was negatively impacting women in developing nations.

To impact a wider network of research possibilities requisite finances need to be made available, however there also needs to be a rightful oversight and transparency on the matter. This where multilateral organizations come into the picture, institutions like UNFCCC and World Bank can help facilitate the oversight of finances, whilst increasing the efficiency quota of the programme management too. Greater transparency of global research funding would give researchers and policymakers a better understanding of what is in the pipeline and help them efficiently allocate time and funding. It could reduce redundancy and serve as a mechanism for research teams to identify synergies and possible collaborators (Overland and Sovacool, 2020).

The symbiotic relationship between energy and climate change is critical to understand how institutions are changing. The United Nations Framework for Convention on Climate Change is critical institutions steering governments, stakeholders and climate science. The convention led to the Kyoto Protocol and the recent Paris agreement. The institutions and agreements under its ageis have transformed energy sectors and pushed fossil fuel dependent countries to redraw their energy mix.

In India's latest VNR, the rationale for achieving energy security is the need for low-carbon development as India's contribution to world's energy-related CO2 emission is expected to grow from 6.7% to 10.6% by 2030 (GOI 2020: 75). This is a slight shift from the NAPCC approach where low carbon development was merely seen as a co-benefit. In the VNR approach, the tone of India's submission is more proactive in terms of addressing increasing carbon emissions. According to the Second Biennial Report submission by the Government of India to UNFCCC, science and technology is considered as a crucial facilitator to meet the requirements and goals for the country's development and energy security in a timely manner (GOI 2018: 175). Thus, development needs, and energy security are core aspects related to proactive and reactive behaviour of India's energy policies. There is no relationship between the trading partners and stance of India's energy security policy in the context of climate change and sustainable development.

Renewable energy has impacted institutional framework in multiple ways. With increasing focus on its global value chain, the geopolitics in this sector is driven largely at the level of manufacturing and end use more than at resource level. Access to primary resources for renewable energy is a critical issue as it also raises question around sustainable mining and the impacts of resource extraction on local communities. However, there are possibilities that raw material use may reduce over a period of time with increasing recovery and recycling technologies.

International institutions have largely been Westphalian in nature and approach with significant developed country influence. With the world becoming more polycentric in nature without a single unilateral power, this norm of international institutions has been continuously questioned by developing countries seeking reforms, India's bid to UN Security Council is a case in example. To establish institutions with more developing country approach, in recent years regional and international organisations have emerged to provide a voice and a platform to raise developing country concerns. In the energy sector, a recent institution to emerge is the International Solar Alliance that is steered by India and France focusing on aggressive deployment of solar energy across the globe. A proactive approach to institutional change and also reforming existing institutions to current challenges has become a norm of the day and this would critical accelerating energy reforms and technological advancements. India's energy choices have a strong resonance at the regional and at global level, transforming approaches and processes in other countries as well.

The concept of barriers and limits to adaptation have been widely used in the IPCC report of 2007, which has a singular chapter titled "Adaptation Opportunities, Constraints, and Limits". Path-dependent institutions are resistant to change. When this resistance causes the changes necessary for adaptation to be slower than changes in climate, then it becomes a limit to adaptation. Indian institutional framework however over the years have become proactive in their approach to absorb the changes that have come their way as the conversations around climate change began to escalate at a global level. Several countries had to make necessary changes to its governance framework to be future ready and better mitigate the repercussions of climate change and environmental degradation.

In 2015, just transition was included in the Paris agreement indicating the need to design a future that phases out coal and other fossil fuels while ensuring that those involved in its processes receive equitable focus and opportunities for a seamless transition to other livelihoods. The concept is rooted in environmental justice. As a coal producing country India needs to ensure that communities, miners and the current land resources under the coal sector are ensured a sustainable transition. Unemployment and labour displacement are key concerns of coal phasing out.

Looking Ahead

Though the concept of energy security has evolved over the past few decades and sometimes considered a redundant terminology due to its strong linkage to conventional fuels. Yet the terminology and the concept is still relevant with various new linkages, advancement in technologies and new global players. There is a need to realign domestic energy structures and outlook to the international commitments and while India has already undertaken several steps in this aspect, further impetus is required at state level. India's internal energy demand and supply structure needs to be harmonized to practice healthy competition, reduce debts and payables and consistent reliance on bailouts by the government.

It is important that moving forward India's institutional framework assumes the position of that of a norm maker in the new and evolving multilateral governance set up to fast track its energy needs. It needs to move away from letting domestic political concerns dominate its global narrative and essential move towards energy liberalization. Climate change is a public good and needs to be assessed from the optics of energy security and market based coordination, a notion which can only be assed from careful international institutional liberation predicated on the principles of reciprocity and diffused reciprocity

There is a growing need for cross border initiatives like OSOWOG to help establish high standards of institutional cooperation, improve intragovernmental transparency, reduce market volatility and possibilities of global market failure. Multilateral and cross border approach to energy distribution may lead a path to more equitable world with high quality energy access. A key aspect to understand in energy sector is the continuous progress in technology and innovation that drives the economics and politics of energy. The discovery of new or novel mechanisms to harness energy to ensure sustainability is leading to rapid advancements that are not dependent on geopolitical ties between states but rather dependent on multiple variables including politics, markets, consumers and producer choices. This multipolarity in energy brings a complexity to International energy governance structures that wasn't visible in the mid-20th century and the 21st century is witnessing a new era of energy security.

Each chapter in this book is discussing one or more threads discussed above. From Just transitions in coal, oil and gas markets, future of natural gas and biofuels, the arc of renewable energy growth (wind and solar), changing dynamics of regional energy discourse including cross border energy trade, impact of climate policies such as EU Green deal and role of new energy institutions all discuss each sector and many of interdisciplinary issues in greater detail. The Indian energy sector is constantly evolving and so is the progression of climate change. All the chapters are the culmination of energy security dialogues that were conducted from 2020-2021, bringing together policymakers, practitioners and academics to provide a wider view of India's energy future.

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INDIA'S CURRENT ENERGY SCENARIO AND SHAPING ITS FUTURE

CHAPTER 1

Realizing India's Renewable Energy Vision 2030

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Background

Ahead of the 21st Conference of Parties to the United Nations Framework Convention on Climate Change (UNFCCC) in Paris in December 2015, India submitted its Nationally Determined Contributions (NDCs) to the UNFCCC, outlining the country's post-2020 climate actions up to 2030. India aims to increase share of non-fossil-based installed electric capacity by 40%, thereby reducing greenhouse gas (GHG) emissions intensity per unit gross domestic product (GDP) by 33%–35% below 2005 levels. In addition, by 2030, the country intends to create an additional carbon sink of 2.5–3 billion tonnes of carbon dioxide through additional tree cover.[1] Increasing renewable energy electric installed capacity to 450 GW by 2030 is a part of the plans for meeting India's commitments.

As of 2019, India's share of global commercial energy stood at 5.8%. Coal accounted for the largest share in commercial energy consumption (54.6%), followed by oil (30.1%); natural gas (6.3%); hydro power (4.2%); modern non-hydro renewables (3.6%); and nuclear (1.2%).[2] There is no authentic data source to quantify the energy consumption through traditional fuels such as charcoal, fuelwood, animal waste, and straw, used mainly for cooking. However, broad-level data from International Energy Agency (IEA) suggest that the share of non-commercial energy has decreased significantly over the years, and constitutes around 20% of the primary energy mix. In 2018, India's per capita carbon dioxide equivalent (CO_2 eq) emission from energy-related activities was 1.71 tonnes/capita, which is nearly 38% of the world average.[3] In absolute terms, India's share in global CO_2 emissions was only 6.8%.

India has an installed grid-connected power generating capacity of 381 GW (as on 28 February 2021).[4] Thermal power, mainly sourced from coal, natural gas, and diesel with 233 GW constitutes 62% of the total installed capacity, followed by renewable energy (wind, solar, small hydro, and biomass) with 93 GW (24.5%), large hydro with a contribution of 46.2 GW (12.2%), and nuclear with 6.8 GW (1.8%) make up the rest. Since 2017, the annual renewable energy capacity addition has been exceeding the addition made through coal-based thermal power. In terms of electricity generation, renewable energy contributed around 139 billion units in 2019–20, contributing over 11% to the total electricity mix.

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1 Details available at <http://www4.unfccc.int/submissions/INDC/Published%20Documents/India/1/INDIA%20INDC%20TO%20UNFCCC.pdf>

2 BP Statistical Review of World Energy 2020

3 IEA: Key World Energy Statistics 2020

4 Ministry of Power. Details available at <https://powermin.nic.in/en/content/power-sector-glance-all-india>

Renewable Energy Outlook 2030

India has declared an aspirational goal of reaching a target of 450 GW of renewable energy capacity by 2030. This is primarily based on findings of the Central Electricity Authority (CEA) study that has estimated electric installed capacity and electricity generation at 817.2 GW and 2518 GWh, respectively, by the end of 2029–30. The generation capacity would comprise 292 GW from thermal, 17 GW from nuclear, and 430 GW (about 52%) from non-hydro renewable energy. Absorption of non-hydro renewables into the grid will require battery energy storage capacity of 27 GW/108 GWh. The study report further states that not all the renewable energy generated will be absorbed in the grid, and the curtailment would range from nil on minimum renewable energy generation day, to 14.6% on maximum renewable energy generation day (Table 1).[5]

TABLE 1: Installed capacity and electricity generation by the end of 2029–30 as per CEA's optimal generation mix report

Source	Capacity		Generation	
	GW	Percentage capacity	GWh	Percentage generation
Hydro (including imports)	66	8.1	207	8.2
Pump storage	10	1.2	4	0.2
Coal	267	32.7	1393	55.3
Gas	25	3.1		
Nuclear	19	2.3	113	4.5
Solar	280	34.3	801	31.8
Wind	140	17.1		
Biomass	10	1.2		

The CEA study seeks to predict the least cost optimal generation mix to meet the projected electricity demand. Although, the analyses have been undertaken at the macro level, it gives a fairly good sense of the direction in which India's electricity system is likely to progress. The share of thermal power installed capacity and generation in the electricity mix would progressively decline and the upward trend of non-fossil fuel power led by solar and wind would continue. In addition, other recent studies have independently corroborated CEA's estimates that about 450 GW of cumulative renewable energy capacity would be required to economically meet the projected electricity demand by 2030.

[5] CEA: Optimal Generation Capacity Mix for 2029-30

Evolving Policy Landscape

Demonstration projects for harnessing renewable energy for grid-connected power generation started in the late 1980s. In the early 1990s, the Government of India formed policy guidelines for promotion of power generation from renewable energy sources. These guidelines, advisory in nature,[6] provided for buy-back price of ₹2.25 per kWh with 5% annual escalation, with 1993 as the base year, concessions regarding the banking, wheeling and third-party sale; and fiscal incentives such as allowing accelerated depreciation for renewable energy projects were proposed. Concerns related to energy security, access, and decarbonization underlined the need for creating a level playing field for renewables through supportive policies.

The Electricity Act, 2003 and its emanating policies established the first major regulatory framework for renewable energy development in the country. The Act was introduced with the aim of empowering State Electricity Regulatory Commissions (SERCs) to ensure that a significant percentage of the total consumption of electricity originates from renewable energy sources. The Act also authorizes the SERCs to specify the terms and conditions for the determination of tariffs. Policy instruments such as the National Electricity Policy (NEP) and the National Tariff Policy (NTP) as revised from time to time, guide the governments and regulators, at both the central and state levels, on various aspects of renewable energy policies, programmes, and also tariff determination.

The policy and regulatory provisions including renewable purchase obligations (RPOs) across the states/union territories have created an assured market and enabled long-term contracts and financing of renewable power projects. The RPO target of 21% (10.5% non-solar and 10.5% solar) by 2021–22, broadly reflects the goal of installing 175 GW of renewable power capacity.

The Government of India's facilitative policies and promotional measures have successfully addressed many of the inherent structural challenges. Waiver of interstate transmission system charges and losses (socialization of the costs amongst a wider consumer base) for sale of power from solar and wind power projects has helped in optimal utilization of best renewable resource locations, thereby reducing the cost of generation. Government of India is investing heavily in augmentation of electricity grid and evacuation of renewable energy from generation points to load centres. Competitive bidding of solar and wind power has introduced standardization and uniformity in the procurement process. Continued focus on improving dispatchability of renewable power

[6] Electricity is a concurrent subject under the Constitution of India, and Centre and States can both legislate on this matter. Matters relating to inter-state transactions are in the Centre's domain while states are responsible for the intra-state sale, purchase, distribution, and supply of electricity.

has yielded encouraging results. Solar and wind power projects, either in hybrid form or in conjunction with energy storage systems, have been successfully bid out and would provide firm power during peak hours and/or pre-determined durations.

Over the period, renewables have transitioned from niche acts to major contributors in the electricity mix. The cost of power generation from renewable energy sources, in many situations, is already competitive to the cost of thermal power generation. However, there is no spontaneous demand for renewable power from electricity distribution utilities. Many reasons are cited for this situation, including existing thermal power purchase agreements (PPAs), and additional costs associated with renewable power integration.

Emerging challenges

Whereas the extant policy and regulatory framework has been successful in increasing share of renewables in the electricity mix, the projected renewable power capacity of 450 GW by 2030 will be confronted with structural, regulatory, and institutional challenges notably poor financial conditions of many state distribution companies (Discoms), access to finance, availability of suitable land, and integrating variable power output from renewables with the grid. The rapid pace of renewable energy development and falling renewable energy tariffs are increasingly making distribution utilities averse to signing long-term PPAs.

In some of the renewable resource-rich states, curtailment of renewable energy is routinely resorted to for preserving grid security. Thermal power plants are required to operate flexibly to balance the variability of renewables, this, however, is accompanied by an additional cost. Integrating higher share of renewables in the electricity grid would require significant investment for augmenting the transmission infrastructure, adding energy storage and other measures for enhancing the flexibility and resilience of the grid.

There are two choices possible for absorption and balancing power from the perspective of future renewable energy capacity. As the first option, the Discoms and transmission utilities would need to undertake system upgradation, demand-side measures including time of day tariff, seasonal tariffs and enhance flexibility of the grid operation to absorb the variable renewable generation. The second option would be to ensure that a major share of the upcoming renewable capacity is increasingly capable of supplying firm and dispatchable power. The optimum approach from economic and technical considerations would lie somewhere in between the two strategies, that is, system-level optimization to enhance absorption capability, and generation-side measures to reduce the need for such optimization. The ability to increase renewable energy absorption would further increase with flexible market instruments like the real-time market which was set to start from June 2020.

Further, mismatch in the projected demand and supply capacity is another major challenge. The pace of electricity generation capacity additions has far exceeded demand growth. There is also a mismatch between incentives for generators, which require attractive payment guarantees to safeguard investments in capacity developed under central or state agency auctions, and the Discoms, which primarily offtake this new capacity for fulfilling RPOs and have to bear the additional costs for integration. Moreover, the electricity pricing regime dis-incentivizes the generators willingness to sell power in market.

Road Map of Achieving 450 GW Renewable Power Installed Capacity

Seamless integration of 450 GW renewable power installed capacity would require an altogether new approach at the federal policy level. The dynamically responsive policy approach would be necessary for addressing the emergent challenges. Some of the likely elements of such an approach are detailed in the paragraphs to follow.

1. **Unlock long-term thermal PPAs:** As the pace of renewable energy capacity addition continues to exceed demand growth, the long-term thermal PPAs would need to be unlocked. With excess power generation capacity, declining renewable energy prices, and increased competition would make short-duration PPAs, say 7 years' duration, an attractive option compared to long-term ones. Conventionally, PPAs for thermal power are modelled around fixed-cost recovery principle. Lower PLF as a result of increasing share of renewables may not lead to financial distress as fixed costs continue to be levied on the purchaser. An assessment suggests that in 2019–20, the variable cost of power from around three-fourths of existing coal-based thermal power plants capacity in major states was more than Rs 2.00. At the current solar power tariffs, most Discoms would be benefited financially by replacing thermal power with solar. However, the frequent and faster ramping required to accommodate short-term variability of renewables requires technical upgradation and is likely to have cost implications.

   Ideally, with declining cost of solar power, the deployment could be accelerated till the solar power output matches the peak day-time demand. To achieve this, thermal power plants could operate in shifts. To balance the day-time variability, gas-fired plants, in addition to hydro, could be utilized. To be effective, such a generation scenario needs to be coupled with 'time of the day' electricity pricing by Discoms, to begin with for industrial and commercial sector. This will incentivize shifting of energy-intensive operations to day-time when low-cost solar power is available. Regulatory provisions for compensating flexibility services by thermal power plants will be critical for larger uptake of renewables. Central Electricity Regulatory Commission (CERC) or State Electricity Regulatory Commissions (SERCs) may address this issue and could specify additional tariff to recover costs on this account.

2. **Integrating renewable energy:** Enhancing flexibility of transmission and distribution grids will be essential for addressing the daily duck curve induced by solar energy and the seasonality of the wind power generation. A number of options are available for this purpose such as strategic energy storage, flexible generating assets, better forecasting and scheduling, enhanced transmission capacity, ensuring strong interconnectivity between various parts of the grid, demand-side measures.

   Already a beginning has been made with renewable energy management centres and 'green energy corridors' across eight renewable-rich states, for efficient management of dispatch and seemless evacuation of renewable power to the load centres. Looking at projections for declining energy storage cost, the focus in the initial years could be on absorbing maximum solar and wind power with minimal storage requirement. The current focus could be towards acquiring cutting-edge energy storage technologies and creating indigenous manufacturing capacity, ultimately leading to cost reductions and enhanced uptake. India's National Mission on Transformative Mobility and Battery Storage has been envisaged with these very objectives.

   While the manufacturing capacities are being planned and costs remain high, controlled deployment of energy storage systems for gaining field experiences would be necessary. Towards this end, the focus on innovative bids for supplying dispatchable power from renewables should continue. This will provide an option to state Discoms to meet their power demand from renewables. Similarly, deployment of other emerging technologies such as hydrogen energy, which could potentially enable broader penetration of renewables in a wide range of economic sectors, would need to be undertaken.

3. **Strengthen merchant power market:** Strengthening green power markets on exchange will help in achieving RPOs, meeting short-term demand at competitive prices, and also grant a window for generators for selling excess power and avoiding curtailment. Real-time power market, launched in June 2020, has provided real-time corrections for both renewables and demand. The green term-ahead-market, launched in August 2020, has allowed selling of power by the renewable developers in the open market without getting into long-term PPAs. However, in order to have a level playing field, various incentives such as Inter-State Transmission System

(ISTS) charges waiver available to projects with long-term PPAs, will require to be made available for solar and wind power traded through exchanges.

4. **RPOs would be necessary:** While the developments are encouraging and generation costs are falling rapidly, there are still a number of major policy and infrastructure reforms that need to be accomplished to make renewable energy competitive in the open market. The challenge is to meet the dual objectives of higher renewable energy share and keeping the consumer tariffs low in the face of slow growth in demand. Left to its own devices, the markets would pull down the renewable power growth trajectory below what is required to achieve 450 GW of renewable energy. It is therefore imperative to continue to support renewables both through some form of affirmative action to ensure sufficient demand and by encouraging technological interventions to make renewable power competitive with other alternatives on the market. From the national perspective, justification for affirmative action in the form of obligations would include the following:

   i. Discoms are averse to renewables citing the additional prohibitive cost associated with integration. Analysis suggests that hybrid renewable power (solar and/or wind with energy storage), both uniform and steady, will cost higher than single-source renewable power, with the cost increasing with duration and quantum of storage.

   ii. The investment into improvements in grid infrastructure and balancing technologies, that discoms and transcos will have to incur to ensure achievement of obligations,would result in lowering the inefficiencies and costs of power distribution and transmission in the long term.

   iii. Although environmental implications and associated costs are often included in economic comparisons between renewable and conventional energy, investors rarely include such environmental costs in the bottom line used to make decisions.

   iv. Renewables are now part of global energy governance primarily for climate change and geo-political energy security-related considerations. International initiatives calling for expansion of renewables (read NDCs, SDGs, etc.) and reduction of fossil fuel energy sources lend a multilateral dimension to renewables' regulation.

5. **Revisit renewable energy certificates (RECs) mechanism:** With solar and wind power tariffs discovered through competitive bidding falling below the Average Power Purchase Cost(APPC) in many states, the extant regulation including REC floor and forbearance price prescription may no longer be appropriate. Under the

present market condition where solar energy has already reached a level of maturity, floor and forbearance prices may create a situation of over-regulation, thus acting as a barrier. However, wind power potential is more location-specific and wind power price decline has not been as rapid as solar. Similar is the situation in regard to other renewable energy technologies such as small hydro power and biomass projects. There may arise a need for floor price or technology-based multipliers for RECs in respect of these technologies to ensure reasonable return on investments.

6. **New modes of financing are to be explored:** Renewable energy goal for 2030 would translate into an investment opportunity of around US$15–20 billion per year. Ensuring payment security and tackling the risks related to delays in payments to independent power producers would be necessary for ensuring investor confidence. Bond market, which assures a constant and low-risk yield for renewable energy deployment would need to be further explored. Other areas for action include low-interest rate, long-term international funding and developing suitable mechanisms for managing currency hedge risk.

7. **Focus on domestic manufacturing:** Deployment of 450 GW renewable energy electric installed capacity by 2030 does not translate into energy security for India. The solar power sector lacks a complete indigenous value chain, and nearly the entire demand of solar cells is met through import. Policies and programmes would need to be oriented towards developing such a value chain in the country in the coming years. Considering the importance of domestic manufacturing, it has been dealt with in detail in the subsequent section.

8. **Innovation would be a key driver:** Looking at global renewable energy trends, it is evident that innovation is a key driver. Innovation has many facets in technology, assembly, finances, and supply chain management. There are three main aspects of it—(i) resource acquisition, (ii) technology development, and (iii) an innovation ecosystem that leverages research and development and skills. A comparison of key indicaters of innovation ecosystem for United States, India, and China is given in Table 2.

9. **Energy storage:** Need assessment and energy storage technology development for grid integration and balancing of variable renewable energy generation require focus. Policies and programmes would need to be in place for deployment of energy storage systems for increasing the grid's flexibility, improving power quality, enhancing capacity of distribution/transmission grids, reducing curtailment of renewable power, etc. These measures would enable seamless integration of large shares of renewable energy into the grid.

TABLE 2: Key indicators defining innovation ecosystem

Variables	India	China	United States
GDP (current US$ bill), 2019	2,875	14,343	21,374
Annual GDP growth (per cent), 10 years' average	6.4	6.7	2.0
FDI inflows as per cent of GDP, 5 years' average	1.8	1.2	1.8
Royalty and licence fees payments (US$ million), 2019	7,890	34,370	42,732
Royalty payments and receipts (US$ million), 2019	872	6,605	117,401
Total expenditure for R&D as per cent of GDP, 2019	0.6	2.1	2.7
Manufacturing trade as per cent of GDP, 2019	13.72	27.17	11.15
Patents granted by USPTO, 2015	3,415	9,814	155,982

Sources: The World Bank (2019)[7], World Economic Forum (2019)[8], UNDP (2019)[9], WIPO (2019)[10], USPTO (2015)[11]

10. **Explore hydrogen energy potential for diversification of renewables:** Programmes and policies would need to be developed to promote generation of green hydrogen from reneable energy sources and faciliating their use in various sectors of the economy in the mid to long term, including integration of renewables, clean transportation, and industry. The objectives would be to enable cost-competitive green hydrogen production, storage, supply and application technologies; developing large-scale globally competitive manufacturing expertise, and putting in place regulations, codes and safety, performance and quality standards in consonance with technology and market development stages. The Government of India's plans for developing and launching a National Hydrogen Energy Mission

7 The World Bank data (2019). Details available at <https://data.worldbank.org/indicator/NV.IND.MANF.ZS?locations=US>, <https://data.worldbank.org/country/united-states, https://data.worldbank.org/indicator/BM.GSR.ROYL.CD>, <https://data.worldbank.org/indicator/BX.GSR.ROYL.CD?locations=IN>

8 World Economic Forum Global Competitiveness Report (2019). Details available at <http://www3.weforum.org/docs/WEF_TheGlobalCompetitivenessReport2019.pdf>

9 UNDP Human Development Index Report (2019). Details available at <http://hdr.undp.org/en/content/2019-human-development-index-ranking>

10 WIPO Report (2019). Details available at < https://www.wipo.int/edocs/pubdocs/en/wipo_pub_941_2019.pdf>

11 US Patent and Trademark Office, USPTO (2015) <https://www.uspto.gov/web/offices/ac/ido/oeip/taf/cst_all.htm>

with clear quantifiable deliverables. This would be a major step in this direction. The Mission would focus on creating volumes, addressing regulations, supporting demonstrations in niche applications, relevant research, and technology development.

Domestic Manufacturing

At present, while India has around 16 GW operational solar modules and 3 GW of solar cell manufacturing capacity, a significant portion of it remains underutilized, as the domestic manufacturers fail to compete with aggressive pricing and rapidly improving performance capabilities offerred by the imported solar PV cells and modules. In addition, there is no commercial production for upstream stages of poly-silicon and wafers in India. In 2019, net import of solar PV systems in the country was around US$2 billion (Table 3).[12]

TABLE 3: India's import and export in solar PV systems (in million US$)

	Year		
	2010	**2015**	**2019**
Export	945.15	112.90	202.30
Import	551.06	1889.20	2089.20

In India, the general impression about solar energy manufacturing is that it lacks a level playing field as compared to competing nations which have access to heavy subsidies and other incentives conducive for large-scale manufacturing. This is further compounded by inherent domestic disabilities such as high cost of finance and commercial electricity, and other infrastructure bottlenecks. An article published in *Business Standard* on 5 December 2020[13], quoting data from the Ministry of Commerce, Government of India states that "Chinese solar equipment imports jumped nearly six times in 2013–14 when tenders for solar power projects were gathering momentum in India. Till 2017–18 imports grew steadily, tapering 24 per cent after 2018, under the combined impact of safeguard duty and slowdown in award of solar projects. Analyst reports show that China has reduced benchmark price of solar photovoltaic panels by more than half to a global low of US$0.15–0.20 per kWh in the past eight months."

[12] Source: UN Comtrade HS 854140 (Photosensitive semiconductor devices, incl. photovoltaic cells whether or not assembled in modules/made up into panels). Comtrade provides international merchandise trade statistics for 170 countries. It is based on HS classification system. Details available at <https://comtrade.un.org/data/>

[13] Business Standard, Delhi, Shreya Jai, 'A power gap for RE players' 5 December 2020

In December 2011, India announced the National Manufacturing Policy (NMP) that aimed at increasing the share of manufacturing in GDP to 25% within a decade. Its two major objectives are to increase domestic value addition and technological 'depth' and to enhance global competitiveness of Indian manufacturing through appropriate policy support. It specifically refers to renewable energy at many places in the context of industries with strategic significance, technology acquisition and development, and special focus sector.[14] In pursuant, in June 2012, the Department of Industrial Policy and Promotion (DIPP) established a Technology Acquisition and Development Fund (TADF) to buy and acquire technologies either nationally or globally. It had specific mention of equipment and/or technologies used to produce energy from the sun, wind, geothermal and other renewable resources. Later in 2016 this scheme was transferred to Ministry of Micro, Small and Medium Enterprises.[15] The 2007 Special Incentive Package Scheme (SIPS), later modified, as part of the Semiconductor Policy with an aim to provide boost to the semiconductor manufacturing sector had also included solar PV.[16] However, these efforts could not materialize and were unsuccessful in creating full value chain of indigenous manufacturing in the PV sector. Comparatively, situation is far better in wind and other renewables where significant indigenous capacities have been developed to build systems, components, and sub-components.

The Government of India's keenness for domestic manufacturing is reflected in a number of recent initiatives and promotional measures. On the demand side, about 40 GW of domestic requirement for solar cells and modules has been fulfilled mainly through schemes such as Central Public Sector Undertaking (CPSU) Scheme Phase-II, PM-KUSUM Scheme, and Rooftop Scheme Phase-II. Since July 2018, a Safeguard Duty has been in place on imports of cells and modules from some countries. Imposition of a Basic Custom Duty (BCD) of 40% on imported modules and 25% on imported cells has been notified, and would become effective from 1 April 2022. In November 2020, the Union Cabinet approved Rs 4500 crore under Production Linked Incentive (PLI) scheme for high efficiency solar PV modules. However, the challenges lie in addressing the fundamentals to encourage manufacturing at scale, particularly, access to critical raw materials, electricity at rational rates, enabling infrastructure, continuity of policy initiatives, focus beyond domestic markets, and linkages with innovation system for resource acquisition, technology development, and process upgradation.

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14 National Manufacturing Policy; Ministry of Commerce 2011. Details available at <https://www.meity.gov.in/writereaddata/files/National%20Manufacturing%20Policy%20(2011)%20(167%20KB).pdf<

15 Details available at <https://dipp.gov.in/sites/default/files/Annexnmp2.pdf>

16 Ministry of Information and Communication Technology. Details available at <https://www.meity.gov.in/esdm/incentive-schemes>

A number of possible incentive mechanisms, including PLI, capital subsidies, interest subvention, etc. have been proposed to enhance competitiveness of Indian solar manufacturing. There is a need to develop an objective mechanism for comparing such incentives in terms of the value achieved against the likely public funding support. To illustrate, such an analysis was undertaken to understand impact of various incentives on the solar PV production cost. Two scenarios for solar PV module manufacturing, commencing with the base material as poly-silicon, and PV cells, were analysed for a manufacturing capacity of 1 GW/annum. For comparison purpose, the following eight indicative incentive scenarios were considered:

i. Interest subvention: financing at 4% lower than market rate

ii. Lower electricity price: 50% lower tariff

iii. Free land

iv. Capital subsidy: 40% of the total capital investment to be subsidised

v. Production subsidy: 5% subsidy on cost of finished product

vi. PLI: 10% of domestic value addition as PLI

vii. Duty-free equipment: 15% custom duty concession on manufacturing machinery and equipment

viii. GST concession on finished product: 5% lower GST rate

The estimated capital and operational expenditure for solar PV module manufacturing, reflecting technology, and cost status for 2020–21, are given in Table 4.

TABLE 4: Estimated capital and operational expenditure

Starting material	Poly-silicon	Cell
Capex in ₹crore/GW capacity (land, building, equipment and support facilities)	2056	340
Opex in ₹crore/GW production (raw material and utilities)	1684	1747

A financial model for calculating the production cost of PV modules based on the costs (given in Table 4) and other assumptions[17] for achieving a reasonable return on equity (IRR: 16%) was utilized. The calculation was repeated under various incentive scenarios, and the results obtained are shown in Figure 1 and Figure 2.

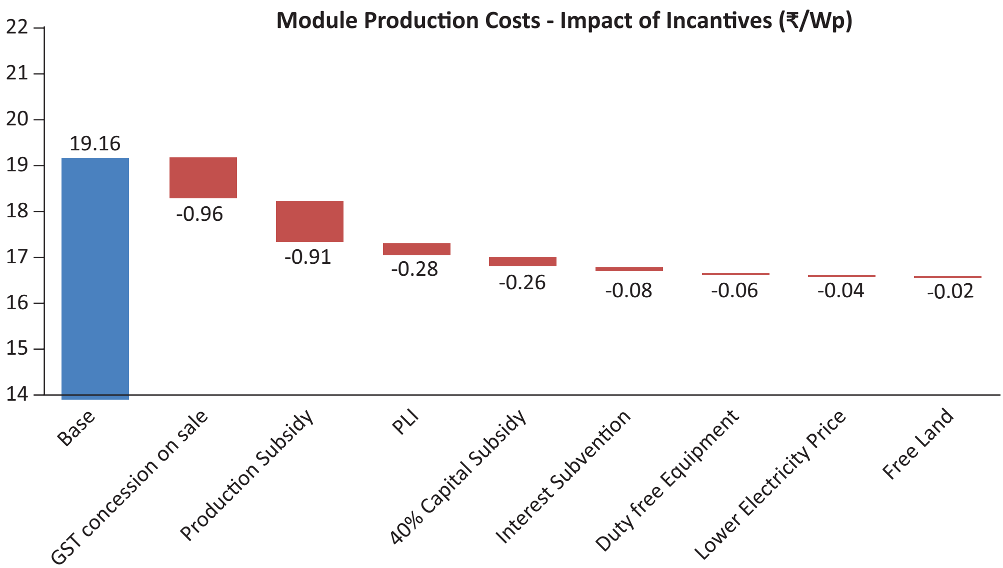

FIGURE 1: Module production costs and impact of incentives, starting with imported cells

The results suggest that impact of candidate incentives on the module production cost would be contingent upon the starting material. The production process starting from poly-silicon is significantly more capital and energy intensive compared to the production from PV cells, hence the impact of capital incentives (Capex subsidy, free land, interest subvention, custom duty concession on equipment) and lower electricity price is visibly greater in the former case. Accordingly, such incentives may be suit manufacturers engaged in fully backward integrated production lines.

PLI based on value addition would also incentivize backward integrated production to a greater extent. A flat production-based subsidy or concessional GST on finished products, is likely to have a similar impact in both the cases.

[17] Term loan interest: 12%, interest on working capital: 13.5%, life of plant: 15 years, base industrial electricity tariff: Rs 10/kWh

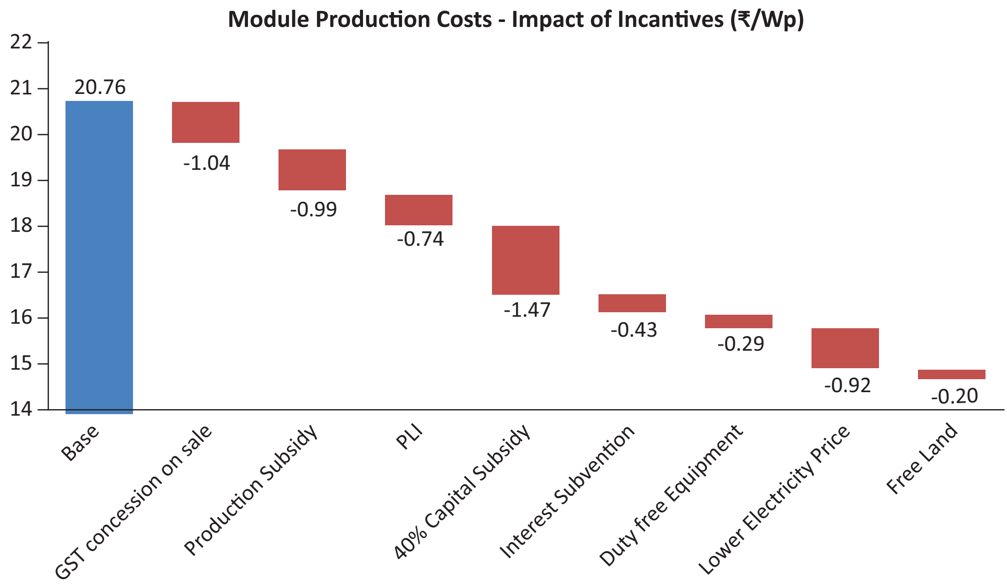

FIGURE 2: Module production costs and impact of incentives, starting with imported poly-silicon

However, in order to understand the true impact of candidate interventions in raising competitiveness of domestically produced modules, it was sought to normalize the impact in production cost vis-à-vis the expected outgo from the government budget (in the form of financial assistance or foregone revenue). Figure 3 and Figure 4 depict the estimated reduction in production cost achieved per unit government spending under the candidate incentive mechanisms.

The analysis leads to interesting insights briefed here:

» Capital incentives, such as capital subsidy, free land, and custom duty concession on production equipment could be more efficient means of bringing down production costs in both cases (cells and poly-silicon as starting material). However, these incentives are limited to the extent of capital requirement. Even if 100% of the capital investment is subsidized, the module price is reduced by only ₹3.9/Wp for production from poly-silicon, and only ₹0.6/Wp for production from cells. While free land appears to be the most efficient incentive, it can only achieve a maximum cost reduction of ₹0.2/Wp for production from poly-silicon, and only ₹0.02/Wp for production from cells.

» There is always the possibility of beneficiaries over-stating of capital investments to access incentives. However, if such potential malpractices could be avoided, the above analysis indicates that capital incentives should be given precedence before other incentives are considered.

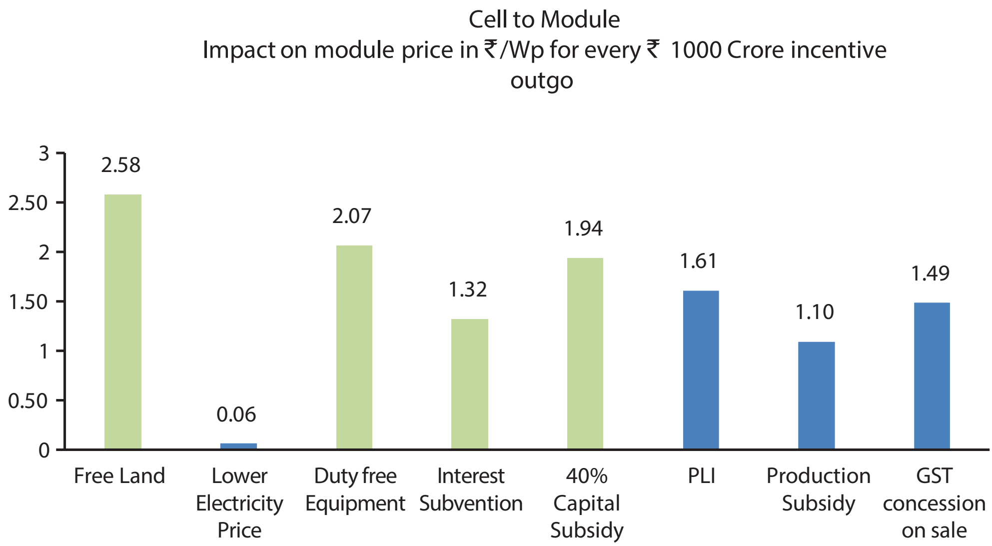

FIGURE 3: Efficacy of candidate incentives on module production from cells

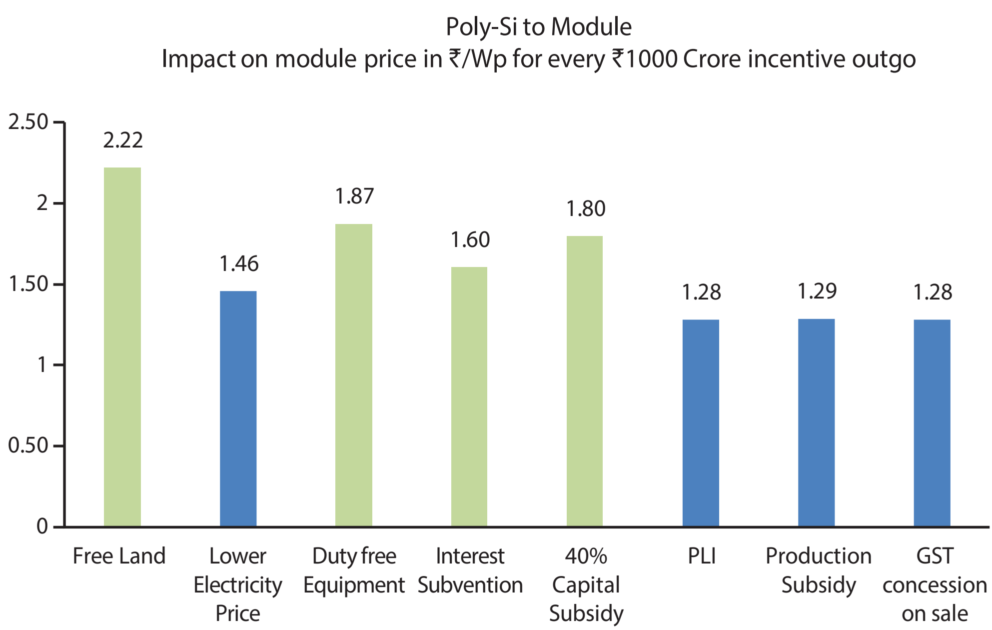

FIGURE 4: Efficacy of candidate incentives on module production from poly-silicon

The preceding case study is based on a number of assumptions that are likely to vary with time, and is accordingly not meant to be a prescription for preferred incentives. It instead provides an analytical framework for comparing candidate incentive mechanism for achieving maximum impact within the limited resources. Based on emergent trends, suitable incentives or combinations thereof to achieve the desired goals in terms of competitiveness in global markets can be devised.

Conclusion

India’s energy projections from various analyses suggest the strategic importance of renewable energy development from the point of view of long-term energy security, and environmental sustainability. The IEA’s *India Energy Outlook 2021* indicates that by 2040, the energy mix in India will become much more diverse, and renewables will meet nearly a quarter of India’s total energy demand. These projections are indicators of ongoing energy transition with three main components: (i) progressive phasing out of fossil-fuels; (ii) large-scale electrification of many sectors of economy; and (iii) decentralization of the energy systems.

For India, success will largely depend on mobilization of the necessary finance and investment on competitive terms; creating an innovation and manufacturing ecosystem in the country; economically integrating larger share of renewables with the grid; enabling supply of firm and dispatchable power from renewables; and enabling penetration of renewables in the so-called hard to decarbonize sectors. The endeavor would be to enable this transition at the least possible economic cost.

Disclaimer: ***Views or opinions herein have been expressed in personal capacity of the authors and do not represent in any way those of people, institutions, or organizations with whom the authors are associated in professional capacity.***

CHAPTER 2

Nuclear Energy in India – Technological Progress, its Role in the Electricity Mix, and Public Perception

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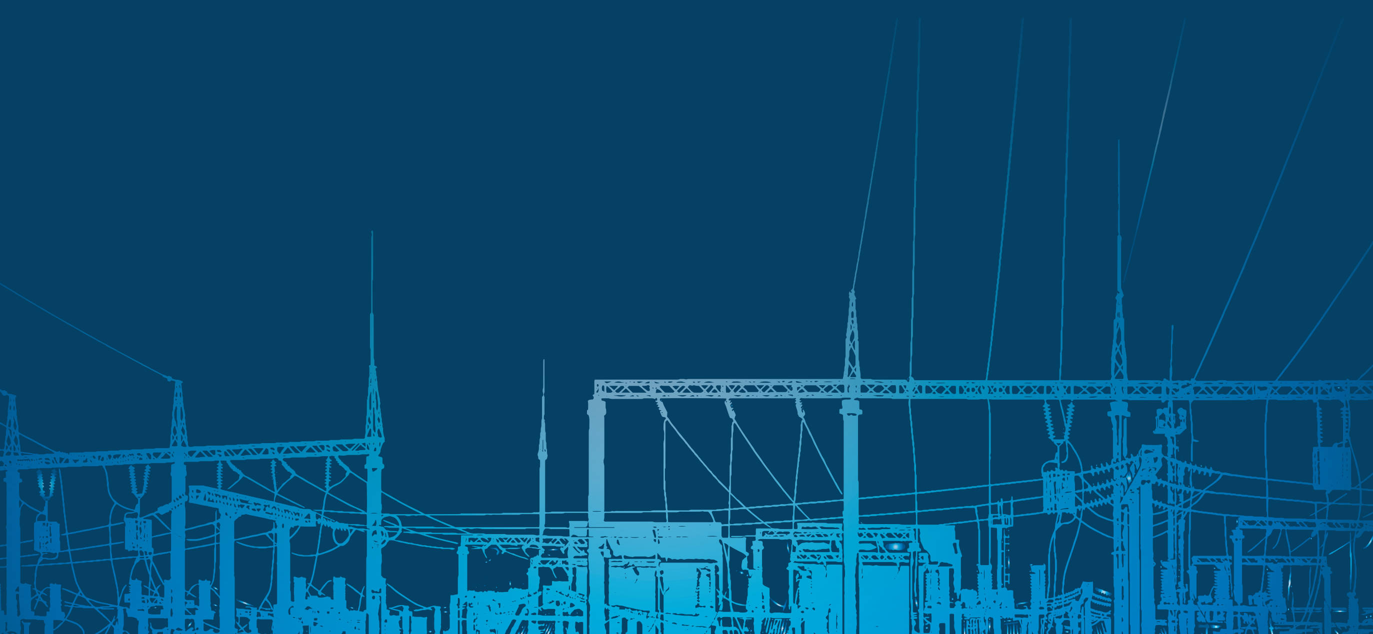

Introduction

To harness the power of the atom, Atomic Energy Committee was set up in late 1945 under the aegis of the Council of Scientific and Industrial Research (CSIR), but activities didn't take off. After India gained independence in 1947, the leadership of the country decided to explore nuclear science and technology for the welfare of the people and other peaceful purposes. Three of the major steps taken in this direction include: (i) the Atomic Energy Committee was renamed Atomic Research Committee in 1947, tasking it with a mandate to plan and implement atomic research, (ii) Atomic Energy Act was passed in April 1948, and (iii) Atomic Energy Commission was constituted in August 1948 under the aegis of CSIR.

On the basis of preparatory work done, over about a decade, the Department of Atomic Energy (DAE) was founded in 1954, and within a span of two decades, it emerged as a formidable organization, consisting of research and development centres, public sector units, industrial units, grant-in-aid institutions, and agencies for extra-mural funding. Detailed studies, conducted at that time, concluded that to upscale people's standard of living, either large-scale import of fuel or development of atomic energy was critical. Considering minuscule deposits of uranium in India, it was decided to pursue a closed fuel cycle programme, which was formulated by Dr Homi Bhabha as a Three-stage Nuclear Power Programme (Grover and Srinivasan 2020). In this regard, two research reactors were built in quick succession—Apsara in 1956 and CIRUS in 1960. Research in physics, chemistry, chemical engineering, metallurgy, reactor engineering, electronics, technical physics, accelerators, lasers, nuclear medicine, biological sciences, nuclear agriculture, food technology, and many other fields was initiated (Sundaram, *et al*. 1998).

Two boiling water reactors were built at Tarapur on a turn-key basis and had been in commercial operation since 1969. Later, it was decided that pressurized heavy water reactors (PHWRs) would be the mainstay of the initial nuclear power programme, attributable to several reasons including the then capability of Indian manufacturing industry and higher plutonium yield per tonne of mined uranium from a PHWR which is a distinct advantage for pursuing a closed fuel cycle. Construction of a first set of two PHWRs was started at Rawatbhata, near Kota in Rajasthan, in collaboration with Canada. The first unit at Rawatbhata went into commercial operation in 1973. To manufacture fuel, Nuclear Fuel Complex was set up in Hyderabad and uranium was procured from mines in Jaduguda, in Jharkhand.

For the production of heavy water in the country, in 1962 a plant at Nangal was commissioned (Sharma and Mukherjee 2009).

Based on indigenous research and development, a plant to reprocess aluminum-clad metallic spent fuel from research reactors was set up in Trombay in 1964. In 1975, a plant to reprocess zircaloy-clad spent oxide fuel from PHWR was commissioned at Tarapur. During the first two decades (1954–1975), India was able to set up research reactors, power reactors, R&D laboratories, and fuel cycle facilities. India conducted a peaceful nuclear explosion on 18 May 1974. This had an impact on the further development of nuclear power, as explained in the next section.

Progress in Indigenization of Technologies During the Next Three Decades

In India, a profile for the growth of nuclear power was issued on 22 July 1970; it identified technologies to be developed, and outlined broad contours of the nuclear power programme. While drafting the profile, it was assumed that international cooperation would continue, as the implications of the Treaty on the Non-Proliferation of Nuclear Weapons (NPT) coming into force on 5 March 1970 had not yet unfolded. However, after the PNE, all international cooperation stopped and India had to follow an autarchic path. Despite this inimical change, during the three decades after 1974, excellent progress was made in the indigenization of technologies (Grover and Srinivasan 2020).

Owing to the suspension of international cooperation after PNE in 1974, the completion of construction of the second unit at Rawatbhata was delayed. It went into commercial operation in 1981, however, this intensified the efforts towards indigenization of technologies. The design of PHWR at Rawatbhata was based on the design of a similar reactor at Douglas Point in Canada, designs of subsequent plants were considerably modified (Banerjee and Gupta 2017). Evolution in design continued and scaling-up was also done, resulting in the setting up of 540 MW PHWRs at Tarapur. The first of the two PHWRs at Tarapur went into commercial operation in September 2005. Significant progress was also made in setting up heavy water plants, expanding fuel fabrication capacity of Nuclear Fuel Complex, developing reprocessing and waste management facilities, completing construction of Fast Breeder Test Reactor, and launching construction of a 500-MW Prototype Fast Breeder Reactor (PFBR) (Grover and Srinivasan 2020).

Technologically, by 2005, India was ready to launch a large-construction programme, but uranium availability was a bottleneck. How this issue was dealt with forms the subject matter of the next section.

Addressing the Issue of Uranium Availability

A study by DAE[18], completed in 2004, indicated that considering continued economic growth and rising electricity demand, coal, though plentiful, is not likely to last beyond the 21st century (Grover and Chandra, 2006). Therefore, the conclusion was that the country has to do all that is necessary for the growth of nuclear installed capacity. The major constraint was poor availability of uranium from domestic sources and no possibility of import of uranium due to discriminatory control regime in the area of international nuclear trade. The situation was so grim that the capacity factor of operating nuclear power plants came down to as low as 50% in 2008–09.

The international nuclear trade is governed by the guidelines of the Nuclear Suppliers Group (NSG), and prior to amendments introduced in 2008, the guidelines didn't permit any sale of uranium to India. This was due to the unique status of India which never signed NPT and has an active nuclear weapon programme (Grover 2017; Grover 2019a). Therefore, a two-pronged effort was launched: a diplomatic effort to have access to uranium from the international market, and a stepping up of domestic efforts to explore and mine uranium in the country. Both initiatives met the desired results. During the last two decades, around 2 lakh tonnes of additional uranium have been located and total reserves now stand at about 3 lakh tonnes of triuranium octoxide (U_3O_8). Mines are now working in Jaduguda region of Jharkhand and Tummalapalle in Andhra Pradesh. Apart from this, more mining operations have been planned.

After a complex exercise, NSG adjusted its guidelines in 2008 to enable India to participate in international civil nuclear trade (Grover 2019a). As a result, both capacity factor and generation[19] from operating plants improved considerably. The capacity factor which was 50% in 2008–09 reached 82% in 2019–20 while generation reached 46,472 kWh in 2019–20 in comparison to 14,927 kWh in 2008–09. On the basis of assured availability of uranium, the Government of India sanctioned the construction of four 700 MW PHWRs: two each at Rawatbhata (Rajasthan) and Kakrapar (Gujarat). The first 700 MW unit at Kakrapar was connected to the grid on 10 January 2021 and the remaining three are approaching completion.

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[18] The study was first issued as a DAE report and was released by the Prime Minister of India at in a function in Kalpakkam on 23 October 2004. It was later published in the journal *Energy Policy*. The study was preliminary, but had a profound effect. Prior to its release, it was examined by Prime Minister's Office. Prime Minister directed the Planning Commission to evolve an integrated energy policy for the country. An expert committee to evolve the policy was constituted and came up with a report titled *Integrated Energy Policy* in 2006.

[19] Increase in generation was partly due to increase in capacity factor and partly due to addition of more reactors.

Subsequent to the above-mentioned four units, two more units were sanctioned by the government for construction at Gorakhpur (Haryana) and currently are in their early stages of construction. More recently, the construction of a fleet of 10 more units was sanctioned. Table 1 lists both under construction and sanctioned PHWRs (Balasubrahmanian 2020). In addition, new sites are being identified for the construction of reactors.

TABLE 1: PHWRs under construction, and approved for construction (unit size: 700 MWe)

S. No.	Location	No of units	Status
1	Rawatbhata, Rajasthan	2	Under construction
2	Kakrapar, Gujarat	2	Unit 3: Connected to the grid on January 10, 2021 Unit 4: Under construction
3	Gorakhpur, Haryana	2 2	Excavation completed, first pour of concrete expected soon Approved
4	Mahi-Banswara, Rajasthan	4	Approved
5	Kaiga, Karnataka	2	Approved
6	Chutka, Madhya Pradesh	2	Approved

Note: A 500-MW PFBR is under commissioning at Kalpakkam. At Kudankulam, units 3 and 4 are under construction and units 5 and 6 have been approved for construction.

Parallel to the PHWR programme, to rapidly augment nuclear installed capacity, India is constructing large light water reactors (LWRs). Two 1000-MW LWRs are currently operating at Kudankulam, two are under construction, and two more have been sanctioned. These plants are being constructed in technical cooperation with Russian Federation. The government has planned to construct more LWR units in cooperation with Russia and other countries (Grover 2017).

In essence, all technical challenges have been addressed and India is set to launch a large-scale programme for increasing nuclear installed capacity in accordance with a strategic plan, based on an integrated approach for the evolution of the electricity mix in India.

Role of Nuclear Energy in the Electricity Mix of the Country

Setting a target for total generation

The steps to ascertain the role for a generation technology in the electricity mix include an assessment of the total demand for electricity, and its examination with reference to fuel resources and technologies available to the country. Development and deployment of technologies are complex and time-consuming activities, therefore, this requires demand forecast over a long-term, say four to five decades. Approaches used for demand forecast depend on a set of assumptions but they do provide some estimates about year-wise growth. To arrive at long-term generation target, one can follow an approach which is based on examination of the correlation between human development index (HDI) and per capita electricity consumption, as illustrated in the scatter plot in Figure 1. Dots in the figure correspond to various countries (Grover 2019a). HDI is a composite indicator for assessing the well-being of citizens of a country and to achieve a high HDI of about 0.9, it is necessary to have a per capita electricity consumption of about 5000 kWh per annum. The correlation between HDI and electricity consumption[20] will continue to evolve due to several factors. An increase in energy efficiency will help in achieving a given HDI at a lower value of electricity consumption. On the other hand, structural changes in the energy sector such as increasing use of electricity in transport, industry, cooking and many others lead to an increase in the share of electricity in the total final consumption (TFC) which is defined as the sum of consumption of energy from various sources by different end-use sectors and also includes non-energy use. These changes will call for a higher per capita annual electricity consumption for a given HDI. According to an estimate by International Atomic Energy Agency (IAEA 2020), the global average percentage[21] share of electricity in TFC in 2019 was 18.8, and is expected to reach 27.2 in 2050. Recent reports mapping a roadmap to net zero project a still higher percentage share of electricity in TFC.

Figure 1: Data for electricity consumption is from Key World Energy Statistics, 2018 (IEA, 2018). Data for HDI is from "Human development Indices and Indicators" 2018 Statistical Update (UNDP, 2018).

In short, the correlation depicted by data in Figure 1 can shift to either left or right, however, one can still use 5000 kWh per capita per annum for planning purposes. Electricity consumption in countries in the neighbourhood of India which have a tropical climate, for instance Malaysia and Thailand, is fast approaching this number, while Singapore has gone way beyond this.

20 This is just a correlation and does not imply any causation.

21 These percentages do not take into consideration total primary energy used to produce electricity. While for converting thermal energy to electricity energy, the conversion efficiency is about 33%, no such conversion is involved in case of hydro, solar, and wind. Until 2016, IAEA (2016) was reporting data based on total energy requirement, and percentages then reported were 37.4 for 2015 and 49 for 2050.

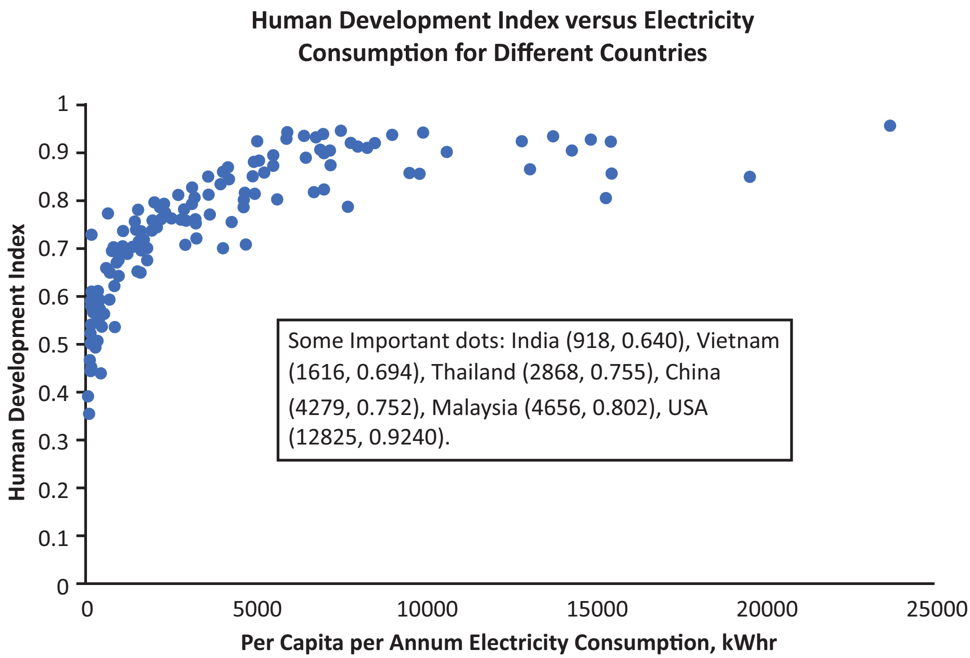

FIGURE 1: Human development index versus electricity consumption for different countries

According to Vollset, *et al*. (2020), India's population will peak at 1.6 billion in 2048. Keeping this is in mind, and assuming that it will be possible to bring down transmission and distribution losses to the technically lowest achievable level, of about 7%, India will need to generate 8700 billion kWh per annum. This is more than five times the electricity generation [from utilities, non-utilities, and renewable energy sources (RES)] in 2019–20, which was about 1600 billion kWh. IEA has forecasted that demand in India (IEA 2020) will rise to only 3700 billion kWh by 2040. It translates into a compound annual growth rate (CAGR) of about 4.3%, while the CAGR for generation from utilities and non-utilities during 2009–10 to 2018–19 was 5.49% (MoSPI 2020). Assuming a long-term CAGR for electricity generation to be 5%, India will reach the target of 8700 billion kWh in about 35 years.

Determining the electricity mix

In order to achieve the target of 8700 billion kWh per annum, the potential and characteristics of available technology options are of paramount importance in the evolution of the electricity mix. As per the Ministry of New and Renewable Energy (MNRE) India has a wind potential of about 300 GW at a hub height of 100 metre, solar potential of ~750 GW, assuming 3% wasteland is made available, and bio-energy potential of 25 GW (MNRE 2020). Assuming a plant load factor of 20%, all these sources together can provide about 1900 billion kWh per annum. In 2019–20, large hydropower plants generated 156 billion kWh. India still has untapped hydro potential and that should be harnessed as soon as possible. It is worth mentioning, even after achieving the full potential of RES such as large hydro, solar, wind and bio-energy, total electricity generated cannot exceed about a quarter of the target generation. The remaining balance has to come through nuclear and coal power generation. Therefore, all technology options, including coal, have to continue to be a part of India's electricity mix.

The observation about the continued use of all technology options is at variance with the views expressed by some experts who are of the opinion that demand for electricity can be met with RES supported by energy efficiency and social norms promoting frugality (Jacobson and Delucchi 2011; Delucchi and Jacobson 2011; Sukhatme, 2012, Jacobson, *et al*. 2015). While significant gains in energy efficiency have been achieved, frugality in energy use is nowhere in sight.

The government of India has launched several initiatives aimed at improving energy efficiency, and these have been successful. However, one has to examine the rebound effect, which refers to the reduction in expected gains from new technologies that increase the efficiency of resource use, because of behavioural or other systemic responses. For example, the programme of the Government of India to promote the use of LEDs was well received, however, one can see that rooms in middle-class residences nowadays have multiple-light sources in place of a single bulb.

Frugality would require lifestyle changes and overhaul of economic systems and both are challenging. Speaking specifically about India, demand for electrical appliances will continuously increase as India has one of the lowest appliance penetration rates in the world (IEA 2020). Slowing down of increase in electricity generation in recent years and almost no increase in the last fiscal is not due to lack of need for more electricity, but because of overdue policy reforms. There is no monitoring of distribution companies (DISCOMs) for the reliability of supply (IEA 2020). They frequently resort to load shedding to manage demand. DISCOMs have no incentive to purchase electricity from power exchanges, as for them more supply means more under-recoveries.

The government has taken note of the inefficiencies of DISCOMs. An announcement made by the Finance Minister, Nirmala Sitharaman in a press conference on 16 May 2020 referred to a tariff policy that will include mandating DISCOMs to ensure adequate power to avoid load-shedding. This initiative will help in meeting demand which is now pent-up.

In brief, demand for electricity has been and will keep on rising. India should be generating about 8700 billion kWh per annum by about the middle of this century. In this regard, deep decarbonization of the energy sector is an urgent necessity, and requires simultaneous action on several fronts including enhancing the energy efficiency of the economy, and evolving an electricity mix that makes use of all low-carbon technologies such as hydro, nuclear, solar, and wind. A silo-based approach to decide targets for the generation of electricity from different technology options has to be replaced by an integrated approach as discussed next.

Evolving Future Electricity Mix

For the evolution of an appropriate electricity mix, besides resources and technologies, one also need to look at characteristics that determine tariff for the consumer, external costs (both positive and negative), biophysical constraints, and the need for diversity. Some aspects related to these issues are discussed in this section.

Determination of tariff

The consumer-end cost of electricity is not the same as the generator-end cost due to the transmission and distribution system that lies in between (Grover 2018). For comparison of cost of generation from various technology options, levelized cost of electricity (LCOE) generation is the most sought method. It is simple and easy to use, however, compares only generator-end costs. It is equal to lifetime costs (present value of the total cost of building and operating a power plant over its lifetime) divided by lifetime energy production. It provides a good basis for comparing technology options with different lifespans. It was devised before the advent of RES and therefore, has no parameter to account for intermittency. Hence, it cannot capture additional balancing costs imposed by intermittency. Energy sources such as coal, nuclear and large hydro are available round-the-clock and the lack of a parameter to account for intermittency in the LCOE method was inconsequential for their inter-comparison. It is worth taking note, when aiming to integrate intermittent RES to the grid, continued use of LCOE as a metric for comparison of technology options is erroneous. LCOE tends to overestimate the economic efficiency of RES and the extent of the overestimate increases with an increase in their penetration in the grid (Ueckerdt, *et al*., 2013).

Attempts made by energy economists to replace LCOE by a simple method have not been successful and complete system modelling is the only way to determine the overall benefit and loss to the electric system from integrating any new capacity (Graham 2018). Given the cost of creating new capacity and integrating it into the grid, modelling can identify benefits of new capacity and loss to existing generators because of integrating new capacity. Adding any new intermittent capacity distorts the load profile of residual generators that can provide electricity 24x7, reduces their plant load factor and also results in wear and tear of the machinery. We will further examine integration costs while discussing grid-level costs.

From remarks made during seminars by experts associated with the electricity industry, one senses a reluctance to move away from LCOE as it is embedded in all industry practices, and any revision of practices is a tortuous task.

Costs at the generator end are plant-level costs and its components are: cost of servicing the capital invested in setting up the plant, and cost of generation (fuel, operation and maintenance). Next are the grid-level costs, which consist of grid connection, grid extension and reinforcement, short-term balancing costs, and long-term costs for maintaining adequate back-up supply.

Integrating RES to Grid—influence on coal-fired plants and tariff

Peak load in India normally occurs in the evening time when sunlight is not available. The manager of the electricity system has to ensure that the available installed capacity is adequate to meet the peak load. Therefore, total capital invested in the electricity system will remain the same whether solar is or is not a part of the electricity mix. When it is a part of the electricity mix, its influence is to reduce the capacity factor of plants that can operate 24x7. Table 2 gives data in support of this remark.

As on 31 March 2020, the total installed capacity in despatchable power plants in the country was 283.079 GW, and installed capacity based on RES was 87.028 GW. Peak demand met during the year was 182.533 GW, which is only 64.5% of despatchable installed capacity. Therefore, if RES were not there, despatchable generators could have met the demand by an increase in plant load factor. Data on plant load factors of previous years clearly indicate that despatchable generators are capable of working at higher plant load factors. This indicates that investment in despatchable generators is not being fully utilized. This has a positive effect as it means less CO_2 emissions, but it also has a negative attribute as it has resulted in a poor return on capital invested in coal-fired power plants. As a significant part of the investment is made by the banking sector, this results in the poor financial health of the sector. The consequences of the poor financial health of the banking sector are ultimately borne by the citizens of the country. This leads one to conclude that while increasing RES-based installed capacity is desirable to address environmental concerns, it comes with a cost.

TABLE 2: Select Data from the Ministry of Power (MOP 2020)

A. Installed capacity as on 31 March 2020

Fuel	MW	% of total
Total thermal	2,30,600	62.8%
--Coal	1,98,525	54.2%
--Lignite	6,610	1.7%
--Gas	24,937	6.9%
--Diesel	510	0.1%
Hydro	45,699	12.4%
Nuclear	6,780	1.9%
Total of despatchable installed capacity	283,079	76.5%
RES	87.028	23.5%
Total installed capacity	370.106	100%

B. Peak Load Met = 182,533 MW (64.5% of despatchable installed capacity)

C. The PLF (coal and lignite based) from 2009–10 to 2019–20

Year	PLF	Sector-wise PLF (%)		
	%	Central	State	Private
2009–10	77.5	85.5	70.9	83.9
2010–11	75.1	85.1	66.7	80.7
2011–12	73.3	82.1	68.0	69.5
2012–13	69.9	79.2	65.6	64.1
2013–14	65.60	76.10	59.10	62.10
2014–15	64.46	73.96	59.83	60.58
2015–16	62.29	72.52	55.41	60.49
2016–17	59.88	71.98	54.35	55.73
2017–18	60.67	72.35	56.83	55.32
2018–19	61.07	72.64	57.81	55.24
2019–20	56.08	65.36	50.26	54.73

*** The paper was submitted on June 13, 2021.*

Determination of tariff—grid-level costs

Renewable energy sources are distributed sources and so the cost of grid extension is quite significant, and the grid is not used all the time as in the case of sources that are available 24x7.

Grid-level costs have been studied in detail by the Nuclear Energy Agency of the Organisation for Economic Co-operation and Development (OECD) and the intermittency of RES has been found to have a strong negative influence on grid-level costs (NEA 2018). Grid-level costs depend on several factors including the resource mix. The presence or planned inclusion of gas-based peaking plants is helpful in optimizing grid-level costs.

The grid-level costs arising from intermittency of RES can be mitigated with the installation of storage devices such as pumped storage or batteries, or by using large hydro plants for load following. Pumped storage is a mature technology, and is cost-effective for long-duration storage, but needs appropriate sites for implementation. The cost of lithium-based batteries is coming down, but is still relatively high. Ongoing research on 'flow batteries' might help in reducing the cost and recent results from the point of long-duration storage are encouraging.

There is a cost attached to storage and has two components: (i) capital cost of creating storage, and (ii) operating cost including round trip efficiency which for many technology options is significantly less than 100%. From a policy perspective, it is desirable to recognize the need for a solution to address intermittency and the associated cost, and one can go in for a solution based on cost-benefit analysis.

In addition to storage, hydro plants could also be used for load following and should be compensated for the resulting wear and tear of the machinery. Another approach could be to set up gas-based peaking plants, but the gas supply in India is not sufficient to power such plants. Demand management with the help of smart meters and appropriate price incentives is also an alternative. The option of operating RES in 'full flexibility mode' also needs to be examined as it has been found to provide operational cost savings (IEA 2020).

All possible solutions such as storage, load following by hydro, or operating coal-fired plant at low capacity factor, have an attached cost. The cost of electricity for consumers in Germany has increased after the integration of more RES (Orr 2018). In India as well, solar- and wind-based on technologies may not lower electricity prices. It is desirable to do system analysis to quantify and attribute all costs. Such analysis can then guide the fixing of the tariff as well as payment to generators and DISCOMs.

External costs

An important characteristic of an electricity generating technology is health externalities arising from the effect of plant emissions on exposed populations. Plant emissions have health effects (deaths, serious illness, minor illness) on those who are exposed to emissions. Health-related external costs were studied in the European Union through ExternE project for about 15 years' period, ending in 2005. The study followed a dose–response approach, where pathways through which pollutants were dispersed were mapped, the dose of pollutants received by humans was estimated, health effects of the pollutants were studied and finally a monetary estimate (lost working days and cost of medication) of the health effect was evaluated. Results are summarized by Markandeya and Wilkinson (2007) and it was found that nuclear has minimum health-related external costs among the electricity generation technologies studied under ExternE namely, lignite, coal, oil, gas, biomass, and nuclear.

Following ExternE, European Union launched another project, New Energy Externalities Development for Sustainability (NEEDS), and this study concluded that nuclear, solar, and wind have low external costs as compared to other technology options (Ricci 2009). A report from the National Academy of Sciences, USA has surveyed various studies including ExternE and provides a useful summary on externalities (NAS 2010).

Another approach is to include health externalities as a part of the social cost of energy generation. This approach has been used in the Economic Survey 2017, Vol II to denote the aggregate of all costs, and besides private costs, includes social costs of carbon, health costs, costs of intermittency, the opportunity cost of land, stranded assets and cost of Government incentives. The survey estimates that the social costs of renewables in 2017 were around 3 times that of coal at Rs 11 per kWh (MoF 2017). The survey strikes a cautionary note, "while investment in renewable energy is crucial for India to meet its climate change goals, such investments be made at a calibrated pace looking into the total cost accrued to the society" (MoF 2017).

The next important characteristics are resilience and the security of supplies. Generation of electricity from a plant can be disrupted on account of non-availability of means of transportation of fuel due to severe weather events, such as disruption of train movements due to fog, chiefly in the northern part of the country every winter. Lockdown, as implemented in response to Covid-19, can also disrupt fuel supplies. Import of petroleum can come under stress due to disruption of supply lanes in war-like situations. Nuclear power plants, where fuel can be stored for long periods, have an advantage over others.

Other externalities which are important for comparing various technologies are price stability, and indigenous capability to manufacture and maintain electricity generating plants, but no models have as yet been formulated to quantify such externalities. Nuclear-generated electricity has price stability, and as stated earlier, the complete supply chain for nuclear power plants has been indigenized. The utilization of nuclear power has some additional positive externalities such as providing system inertia and reactive power to the grid.

Biophysical constraints—understanding EROI

Biophysical constraints on economic growth, in general, and on energy use, in particular, are under discussion in acknowledgment of the fact that production takes place only with some use of natural resources including energy. Energy is more important for production than either capital or labour (Hall and Klitgaard 2018). This has given rise to the field of biophysical economics which acknowledges that transformation of inputs into outputs needs energy and natural resources, and any process that needs energy is subject to laws of thermodynamics. Traditional economists believe that any resource scarcity or degradation of Earth systems can be remedied by technological advances. On the contrary, biophysical economists opine that one might reach non-reversible tipping points if issues of resource scarcity and degradation are not addressed well in time (Hall and Klitgaard 2018).

With regard to energy resources and technologies, net energy gain to society is a defining characteristic. In the 1970s, this was expressed in terms of life cycle assessment of energy flows, and now it is expressed in terms of the ratio 'energy returned over invested' or EROI. To get energy from any resource, say petroleum or coal, one has to invest energy to extract the resource, to process or convert it before being put to use, to transport or transmit it to the consumer, and build infrastructure to carry out all steps. Energy for society or energy gain is the difference between the output energy and input energy. The importance of EROI can be understood with the help of Figure 2 (Mearn 2008). Points on this curve are based on the solution of the following equations:

$E_{out} = 100;$

Energy Gain = $E_{out} - E_{in};$

EROI = E_{out} / E_{in}

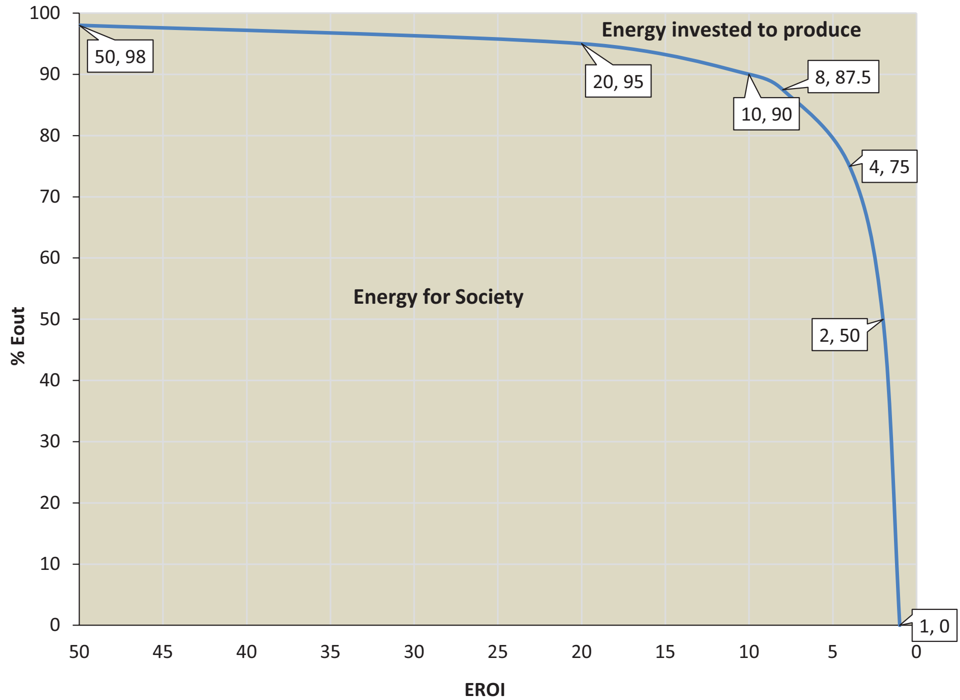

FIGURE 2: Energy cliff

The curve derives its name—Energy Cliff—from the steep fall in energy for society as EROI falls below about 6. A low EROI implies that the size of the 'energy enterprise' that is a requirement of energy resources, manpower, materials, land, etc. is very large and so is the impact on the environment. EROI calculations are done using life cycle energy flows as energy is needed both directly and indirectly: directly at the mine or oil well and indirectly for manufacturing equipment and components for setting up plants, for transportation or transmission including setting up of the needed infrastructure, and also for eventual disposal of decommissioned plants. There is a divergence in EROI estimates by different researchers, mainly due to methodological issues. Issues involved are the consistency of system boundary chosen for analysis, the convention followed for the addition of energy inputs from different sources such as hydro, nuclear[22] and coal, the difference between

[22] In case of nuclear, an additional issue arises between old studies and recent studies. Earlier uranium enrichment plants were based on diffusion technologies and new plants use gas centrifuge technologies. There is a significant difference in consumption of energy between two technologies, and this influences EROI.

the EROI of the source and EROI of the energy supply system of the society calculated on the basis of TFC, accounting of energy invested in the supply chain, treatment of energy invested in imported resource or equipment, etc. In the case of RES, accounting for EROI of storage solutions to address intermittency is an additional issue.

Recent publications address these issues appropriately and may be referenced for details (Neumeyer and Goldston 2016; King and Bergh 2018; Brockway, *et al*. 2019). Neumeyer and Goldston (2016) have calculated both static and dynamic EROI. Dynamic EROI captures the dynamics during rapidly changing energy transition as energy investment is needed to set up a new generator. Irrespective of differences in details, there is an agreement that technologies like fossil fuels, large hydro, nuclear, and wind have high EROI, while solar is about the point where steep fall begins. When combined with storage, EROI of solar falls further. Because of the large energy spent in the collection of the resource, bio-fuels have very low EROI. The decision to use energy sources with very low EROI largely depends on the value of positive externality associated with such sources.[23]

Biophysical constraints: setting a target for EROI

Until an externality is quantified, and the industry is mandated to account for it, the onus of considering its implications on society lies on the government. Speaking specifically, EROI can be an important tool for energy planners to arrive at the electricity mix of a country. One can think in terms of EROI of an individual source or in terms of the nation as a whole. Estimates have been made even for global EROI with a view to understand its influence on the global economy (Brockway 2019). This is an emerging area of research, however, some opinions have already been articulated. Lambert, *et al*. (2014) have estimated that for a society having EROI less than 15 to 25, quality of life is likely to be poor. A higher standard of living can be expected only when EROI is above 20 to 30. Authors have devised a 'pyramid of energetic needs' similar to Maslow's pyramid of human needs. At low EROI, energy for discretionary spending is not available. This is also stated by Brandt (2017) and his list of discretionary activities includes advanced education, science, entertainment, temperature controlled spaces, and discretionary travel. EROI is closely related to the energy intensity of an economy and for the US economy, Fizaine and Court (2016) state that it requires a primary energy system with a minimum EROI of 11 to enjoy a positive rate of growth.

Estimates also indicate that with the depletion of resources, EROI of fossil fuels, particularly oil, would become comparable to RES (Brockway, *et al*. 2019). This has

[23] Example can be a power plant designed to produce electricity using stubble as a fuel, thereby eliminating pollution caused by burning stubble in fields.

implications for long-term economic growth. As the oil industry starts exploiting more and more unconventional oil, it will accelerate resource acquisition rate, and is most likely to result in degradation of the natural environment (Murphy 2014). The decline in EROI puts into question the consistency and soundness of the green growth narrative as is being presented (Capellan-Perez, *et al*. 2019).

Another often-mentioned biophysical constraint is the use of scarce materials in various generation technologies. Recent estimates do point towards a likely scarcity of certain materials (tellurium, indium, tin, silver, and gallium) in case of a very large deployment of solar energy. To obviate the scarcity, research and development efforts have to be directed towards evolving a recycling friendly design of products and technologies (Capellan-Perez, *et al*. 2019). International Energy Agency has listed copper, cobalt, nickel, lithium, rare-earth elements, chromium, zinc, platinum group metals and aluminium as critical minerals for clean energy technologies, and as per their analysis, hydropower and nuclear have low mineral requirements (IEA 2021).

Remarks on evolving future electricity mix

Opinions expressing both extremes that only renewables can provide all electricity needs at the global level, as stated earlier, and the opposite view that nuclear energy is the silver bullet (Brook, *et al*. 2018) exist in the literature. Regarding nuclear, there are opinions that point in the direction of its military ancestry and continued linkage with weapons, while in the case of renewables, there are opinions that cite "a disconnect exists between discussion of renewable energy development and the biophysical limits constraining that development" (Day, *et al*. 2018). Clack, *et al*. (2017) have pointed that the proposal by Jacobson, *et al*. (2015) to power the US electricity grid with 100% intermittent wind, water, and solar uses invalid modelling tools, contains modelling errors, and makes implausible and inadequately supported assumptions.

For electricity generation and associated waste management, issues to be examined are: safety, security of supply, resilience (against severe events, both natural and man-made), environmental effects, resource durability, availability and viability of the technology. Only resource durability and select environmental effects cannot be the determining factors. An analysis which accounts for all the issues does not lead to yes or no as an answer for any technology (Kermisch and Taebi 2017). Essentially, we need a mix of all low-carbon technologies, that is, nuclear, solar, wind, hydro, and coal (with pollution abatement measures and carbon capture and use when developed).

The foregoing discussion supports the adoption of an integrative approach, based on analysis of complete electricity system, rather than an approach where targets are set in silos. Considering the importance of diversity, the need for decarbonization, and accepting that no single technology is a silver bullet, it is preferable to adopt a combination of multiple measures as proposed by Socolow and Pacala (2006). Clack, *et al*. (2017) also recommend that a broad portfolio of energy options would facilitate an affordable transition to a near-zero emission energy system.

We have seen that there is a large gap between the target for electricity generation in India and the potential of solar, wind, and hydro. This gap encourages increasing energy generation from nuclear, hydro, solar, and wind sources with continued use of coal for electricity to meet the residual demand. However, only those coal-fired power plants should be deployed that have high thermal efficiency and are equipped with pollution-abatement measures. Research on carbon capture and use should be stepped up so that coal can continue to be a part of the electricity mix for a long time to provide diversity, and keep EROI at a high level.

Development of Nuclear Technologies for the Future

Nuclear power reactor technologies

India is developing nuclear power technologies on several fronts. Amongst various technologies, the development of fast breeder technologies is most advanced at this stage. A fast breeder test reactor has been operating at Kalpakkam since 1985. At the same site, a 500-MW PFBR is expected to be commissioned by 2022. This reactor has been designed and manufactured based on indigenous effort and will be a forerunner of similar reactors to be constructed after obtaining feedback from its operation over a period of about 1 year (Puthiyavinayagam, *et al* 2017). The development of fast reactor technology is a *sine qua non* for closing the fuel cycle, and by deploying multiple recycling, it will enable realizing the full energy potential of the uranium fuel and make it possible to use thorium as a fuel. When uranium is used in a once through cycle, less than 1% of the energy potential of uranium is realized, and theoretically it can be increased to 100% by pursuing a closed fuel cycle. The extent of multiplier, of course, will be determined only by actual implementation. In view of this large potential, a closed fuel cycle has been called as 'near renewable source' of energy.

As stated earlier, LWRs are also being set up in India to rapidly augment nuclear installed capacity. India has indigenous capability in designing and constructing compact pressurized water reactors (PWR) (Revi 2016). Taking expertise so developed as a base, India can design and construct PWRs on its own, and this is being extensively studied within the Department of Atomic Energy. Two views have emerged from the study. One is to go in for a PWR of large size, about 900 MW, and preliminary design for this size has progressed to some extent (Kumar 2015). The other view is to go in for a rating for which the manufacturing of equipment, particularly pressure vessel, is within the capability of the industrial infrastructure as available in the country. An examination of the present industrial infrastructure in the country indicates that it is feasible to go in for a rating of about 450 MW. The exact rating will be firmed up after further design work and dialogue with the industry. After setting up the first unit, one can scale it up at a later date.

Conceptual studies with regard to advanced reactor systems and hydrogen production are also being carried out and projects to construct them will be launched, when the studies reach a level of maturity and funds are available (Dulera, *et al*. 2017; Vijayan, *et al*. 2015).

In brief, the technology base in the country should also be used to develop next-generation reactor systems which aim to improve safety, sustainability, efficiency and reduce cost.

Recycle technologies

Since India is pursuing a closed fuel cycle, its strategy for waste management is different from those countries who are pursuing an open fuel cycle. In the case of the open fuel cycle, also called once through cycle, spent fuel is considered as waste and is disposed. While pursuing a closed fuel cycle, spent fuel is reprocessed to recover plutonium and uranium for recycling in fast reactors, and the remaining high-level waste is immobilized in a glass matrix by a process called vitrification. Vitrified high-level waste remains radioactive for a long time because of the presence of minor actinides. Volume and radiotoxicity of high-level waste can be reduced by separating minor actinides through a process called partitioning. This significantly reduces radiotoxicity as minor actinides contribute a major share to radiotoxicity. Minor actinides can be mixed with the fuel of a fast reactor and transmuted.

India has set up reprocessing plants to recover plutonium and uranium from spent fuel. In addition, the country has set up an industrial-scale demonstration plant for the partitioning of high-level waste. Earlier reprocessing and waste management facilities were set up as separate units, but new plants will be integrated nuclear recycle facilities and the first such plant is coming up at Tarapur. India's capability in the area of reprocessing and waste management has been detailed by Natarajan (2017) and Wattal (2017).

Development of fusion reactors

Nuclear reactors operating in India and elsewhere are based on nuclear fission reaction. Research and development are in progress to utilize nuclear fusion reaction as the basis for operating nuclear reactors. The Institute for Plasma Research (IPR), Gandhinagar, is working to develop fusion technology. Two Tokamaks are working at IPR, and based on the expertise already acquired, India has joined an international effort in this area which is to establish a facility in France. This facility, called ITER, is a joint endeavour of seven members – China, the European Union, India, Japan, Russia, South Korea, and USA. Further development work regarding setting up the next Tokamak in India will be taken up based on experience already available in the country, experience gained from participation in the ITER project, and results of ongoing global research, particularly in the area of magnets, which has the potential of reducing the size of a fusion reactor.

Challenges and Perception

The remaining challenge

India has fully indigenized all steps involved in setting up a nuclear power plant (based on PHWR concept), right from design, manufacturing equipment, building the plant and operating it. In view of its minuscule natural uranium resources, India has to import uranium, however, fuel fabrication is done in India itself. After the amendment in guidelines of the Nuclear Suppliers Group in 2008, issue of uranium import was resolved. Uranium is a calorie-dense fuel, hence its storage to cover requirements of several years is feasible. In fact, the government is following a policy of storage to keep any disruption in supply at bay. Expert human resource exists in the country, and based on a unique concept, the capacity to train experts for the future has also been created. The unique concept is the setting up of Homi Bhabha National Institute, which has enabled research and development centres of DAE to be constituent institutions of a university (Grover 2019b). The challenge that remains is locating sites for setting up nuclear power plants and this requires addressing the issue of perception discussed in the ensuing section.

Perception

The issue of perception is a result of two narratives. One arises from the fact that civilian nuclear technology was introduced to the world by dropping of bombs at Hiroshima and Nagasaki. The second narrative arises from the notion that nuclear is expensive as compared to renewables and fossil fuels. We will examine both the narratives one by one.

Many countries oppose the utilization of nuclear power to prevent the proliferation of nuclear weapon technology. To shape public opinion, arguments related to non-proliferation are combined with arguments related to nuclear safety. Non-proliferation is not an issue for India as it follows a stringent export control regime, and has harmonized its control lists with that of the NSG.

The argument on safety revolves around nuclear waste management. The world has already witnessed three catastrophic accidents—Three Mile Island, Chernobyl, and Fukushima. Regarding waste management, the way forward is to adopt a closed fuel cycle, and opt for actinide partitioning, followed by transmutation of actinides in fast reactors. This has now been recognized and a majority of concepts proposed by Generation IV International Forum (GIF) are based on the pursuit of a closed fuel cycle (Magwood and Paillere 2018). India is already pursuing fast breeder reactor technology.

Critics of closed fuel cycle point towards security and non-proliferation hazards for the present generation arising from dealing with large quantities of fissile material, but its proponents highlight its benefits in terms of increased resource durability, safety, and security for the future generations. This becomes a case where one can see an ethical clash between the interest of the present generation and the future generations (Kermisch and Taebi 2017). A decision has to be made by the present generation by introducing appropriate safeguards to protect the interest of both the present and the future. India, after weighing its fuel resource position and security imperatives, has decided in favour of a closed fuel cycle. As stated earlier, others pursuing reactor concepts advocated by GIF are moving towards such a position.

Nuclear reactor design follows an approach called defence in depth and provides multiple barriers to ensure that there is no release of radioactivity in the public domain. A stringent regulatory regime ensures that safety concepts are actually adopted and lessons learnt from the previous accidents are used to incorporate improvements in all operating reactors. This has led to continuous improvements in reactor design and operation. Three Mile Island accident didn't result in any release of radioactivity in the public domain, accident at Chernobyl happened because of a faulty design, and Fukushima happened because the plant owner and the regulator ignored expert advice which was based on historical tsunami data. The nuclear industry has learnt from all three accidents. Design changes, setting up of appropriate institutional mechanisms, and improved regulatory practices are the outcomes. The nuclear industry is the only industry which has set up an institution like the World Association of Nuclear Operators (WANO) for peer reviewing nuclear power plants.

If one looks at data related to fatalities on an overall basis, nuclear power plants have the lowest fatalities rate in terms of fatalities per terawatt-hour of electricity generated (Ritchie 2020). Kesavan (2014) writes, "No radiation-related deaths or acute diseases have been noted among the workers and general public exposed to radiation from Fukushima nuclear accident". Ritchie also writes that at Fukushima, substantial changes in future cancer statistics attributed to radiation exposure are not expected to be observed.

Jaworowski (2010) has made detailed observations on the Chernobyl disaster and has commented that projection of the future health of the people officially labelled 'victims of Chernobyl' based on linear no-threshold (LNT) assumption are not borne out by the epidemiological data. As per Jaworowski and Kesavan, LNT assumes that even near zero radiation dosage can lead to cancer deaths and hereditary disorders (Jaworowski 2010; Kesavan 2014). The use of LNT assumption for decision making in the aftermath of the accident at Fukushima led to the evacuation of a larger number of persons than necessary, resulting in suffering, traumatization, and pauperization of evacuees from moderately contaminated areas. These observations call for a rethink of the basis of evacuation following a nuclear accident; at very low doses, it may be safer not to evacuate and spare the public from the trauma that evacuation entails. This will also be helpful in site selection, which is a difficult issue in India because of the high density of population.

The second narrative is about the cost of electricity generated by nuclear power plants. As discussed, the cost at the consumer end is different from the cost at the generator end. Common narrative compares costs at the generator end by using a metric that has no term to account for intermittency and erroneous conclusion so arrived at has distorted policies. The consumer is concerned with the cost at his end, and the common narrative, by its silence about it, is not providing correct information to the consumers as well as policy makers.

Addressing these issues requires a deep engagement with civil society, making evidence-based explanations to balance prevalent narratives. In parallel, the nuclear industry has to work continuously to elevate the standards of safety.

Concluding Remarks

Technology has been expanding practical possibilities for humans, and the pace of technological evolution accelerated after humans started using energy from fossil fuels to power machines (Grover 2019c). However, until about the beginning of the 20th century, an inventor, alone or assisted by a small group, provided technical innovations, and technology evolution was characterized by a slow pace and small size of the technology enterprise. This allowed the social selection process, supplemented with trial and error to determine the viability of a new technology and one can say that technology evolved in an organic manner. This has now changed due to several factors including increase in the size of the technology enterprise, the rise of military–industrial complex, the sophistication of technology, the rise in demand due to the rise in population and consequent effects on the environment, and rising aspirations calling for still further sophistication. Consumer-driven organic process for evolution of technology has been replaced by advertisement-driven sales techniques by large corporations. Public regulatory authorities, established in response to increasing sophistication and use of technology and safety concerns, have replaced consumers as the selector of technology. Technical sophistication has also replaced do-it-yourself servicing by either single-use appliances (or parts thereof) or servicing by expert personnel (Brooks 1980).

Using biological evolution as a metaphor for technological evolution and innovation, Brooks (1980) argues that superseding of the organic process of evolution of technology by corporate and political interest is being criticized by both the Right and the Left albeit using different arguments. Brooks opines, "The Left sees the generation of new technology as having been taken over by concentrated corporate power in alliance with government, especially the military; the Right sees the evolution of technology as being increasingly distorted by political intervention and the creation of perverse incentives by government" (Brooks 1980). Such dichotomous views need examination.

In view of its technical, social, economic, and environmental dimensions, technology influences us through multiple ways including improvement in living standards, health and well-being, the evolution of culture and institutions, and defence and stability of a nation. Even if a country, because of cultural heritage or resource constraints, shows a willingness to manage with less technology options and less energy, the threat to defence, stability, and economy from competing countries will restrain it from doing so. Also, to expect a developing country in a globalized world to be satisfied with less because of their cultural heritage or global environmental concerns is a chimera.

In view of bio-physical constraint, one has to examine the extent to which one can shape technologies to meet the expectations of the developing world. This issue enters the discourse on technologies via the concept of sustainability—a concept that is shaping the debate on pathways to be adopted for further development. In this regard, it is desirable to be in synchronization with the 17 Sustainable Development Goals (SDGs) formulated by the United Nations. These goals are clearly interconnected and crucial to the well-being of the world. However, businesses are overlooking the connectivity of SDGs and cherry-picking the goals (Voulvoulis and Burgman 2019). Even academics are misusing the concept of sustainability for greenwashing and rhetorical purposes.

Sustainable solutions require holistic knowledge generated from several disciplines notably science and technology including environmental science, sociology, and economics, and integration of several perspectives. A binary view of potential sustainable features of a technology is likely to lead to hastily dismissing or endorsing a technology (Kermisch and Taebi 2017), but a holistic examination is not likely to result in a binary view. A narrow approach will not yield viable options, this calls for the adoption of a multi-pronged approach.

As already explained, different energy technologies have different characteristics. It is desirable that a diverse mix of technologies is selected to realize the benefits of diversity. Only a diverse mix can provide security of supply, resilience against severe events, and grid stability, and enable India to achieve deep decarbonization. India should adopt a three-pronged approach: (i) moderate and disciplined use of energy and electricity without compromising development agenda, (ii) improvement in the energy efficiency of all sectors of the economy, and (iii) a diverse electricity mix that includes all low-carbon technologies that is hydro, nuclear, solar, and wind. In addition, coal-fired plants with efficiency improvement and equipped with pollution abatement measures should continue to be a part of the electricity mix until all the low-carbon sources are able to provide the target demand. Generation targets for various technology options should be decided based on a holistic analysis rather than a silo-based approach and all low-carbon technologies should be provided with a level playing field in terms of availability of finance, siting and obligations for purchase by DISCOMs. To the extent possible, the supply chain for setting up generation capacity should be indigenized.

In the Indian context, nuclear energy has to be an essential part of the electricity mix and therefore nuclear installed capacity needs to be ramped up fast. Its supply chain has been indigenized, research and development base has been created to develop advanced technologies, and capacity for manpower training in the country has been established.

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CHAPTER 3:

Natural Gas in India's Energy Mix: Markets, Politics, Policies, and Prices

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Until the COVID-19 virus swept like a tidal wave across the globe, quashing energy demand, the popular verdict was that sustainable and clean energy resources would rule the global energy sector over the next few decades. India too had set a target of achieving 225 GW of installed renewable energy capacity, including hydropower, by 2022, and 450 GW by 2030 (*The Economic Times* 2021a). Interestingly, many oil and natural gas companies were opting for alternative fuels in their portfolios. For example, Gas Authority of India Limited (GAIL), in its 2019/2020 annual report, not only announced its ambitious renewable capacity expansion plans but stated that its existing renewable energy portfolio was around 130 MW, which included 118 MW of wind power capacity and 12.3 MW of solar power capacity. The company is also exploring the prospect of acquiring stakes in the assets of existing renewable energy companies and participating in solar park tenders as a producer, besides venturing into the Compressed Bio Gas (CBG) business by setting up CBG production projects (Mercom India 2020). The state-owned power generator National Thermal Power Corporation (NTPC) Ltd. also announced that a fourth of its power generation capacity would be based on renewable energy sources by 2030 from the current 62 GW to 130 GW by 2032 (The Economic Times 2020b).

But the COVID-19 pandemic appears to have pushed the timeline for the renewable energy era back. According to some reports, the pandemic-induced 40-day lockdown from March 25, 2020,resulted in a dip of 30% in the energy demand, with the power demand alone droppedby 15% (Bhaskar2020).Also, in the first half of 2020,the Indian solar market slowed down substantially, with new installations totalling only 1.3 GW – a 60% drop compared to 3.2 GW a year ago (Mercom India n.d.). However, as per an ICRA report, the demand for power in India has been increasing steadily since then, and by August 2020, the demand was restored to the level it was a year ago (*The Times of India* 2020).

India suffers from a gap between energy demand and supply. With policies such as 'Make in India' and '24x7 Power for All', the gap widens due to exponential growth in the energy demand. Recently, at the India Energy Forum, Prime Minister Narendra Modi said that India is a bright spot in an otherwise challenging year for the energy sector which is evident from the substantial investments that the country has been drawing across the oil and gas value chain (Dhoot 2020).The International Energy Agency (IEA) too recently reiterated its faith in India's position as one of the drivers of global energy demand. In its recently released flagship publication, *The World Energy Outlook 2020*, its executive director, Fatih Birol, said that India would lead the energy demand globally over the next 10 years (IEA 2020a).More to the point, in its Stated Policies Scenario (STEPS), the outlook for natural gas indicates a significant growth, mainly in Asia, as against its outlook for other fossil fuels such as oil and coal (IEA 2020b).

Given that coal and oil are no longer seen as sustainable to meet India's commitment to cut emissions, can natural gas fill the gap left by receding coal and renewable energy-based generation, albeit as a bridge or intermediate fuel? In comparison to oil and coal, natural gas has lower carbon-emitting properties, high calorific value, abundant reserves, and versatility in use across sectors.

In India, where energy demand is expected to rebound and burgeon over the next decade, taking fossil fuels off from the country's energy portfolio is not feasible. Hence, while the government has stated that enhancing renewable energy would remain a priority, it would also focus on increasing the share of the natural gas sector in its overall energy basket. At the Energy Forum held in October 2020, the Prime Minister stated that among India's seven key drivers of change in the energy sector, accelerated efforts towards a gas-based economy would be a priority. The other six areas include cleaner use of other fossil fuels such as oil and coal; greater reliance on domestic sources to drive bio-fuel; achieving the renewable energy target of 450 GW by 2030; increasing the contribution of electricity to decarbonize mobility; focus on emerging fuels including hydrogen; and digital innovation across the systems (Dhoot 2020).

India has set a goal of increasing the share of natural gas to 15% by 2030. Interestingly, this is not a new target. Under the UPA government, in the 2013 'Hydrocarbon Vision 2030', it was outlined that the share of natural gas in the energy mix of India is expected to increase to 20% in 2025 (Industry Group for Petroleum & Natural Gas Regulatory Board 2013). Thereafter, in 2016, the NDA government announced the 15% goal. Yet 4years later, the Indian gas market continues to languish.

The demand for natural gas in the domestic market is largely driven by the fertilizer sector (28%), followed by the power sector (23%), city gas distribution or CGD (16%), refinery (12%), and petrochemicals (8%). The fast-paced economic growth and focus on manufacture envisaged the need for more gas to keep up with the increasing demand. Instead, with the COVID-19-induced restrictions, the demand for gas for power generation, compressed natural gas (CNG), refineries, and petrochemical production during the April–August quarterin 2020 plunged, the exception being the fertilizer industry and piped natural gas (PNG) segments (*The Financial Express* 2020). In fact, despite the massive investment in the infrastructure to make gas more readily available to consumers, the share of gas in India's energy basket is expected to rise to only 10%by 2025, according to E S Ranganathan, GAIL Director (Marketing) (The Economic Times 2020c).

Several factors have contributed to the lag in the country's gas industry. This chapter looks at the issues that have a bearing on the Indian gas sector and analyzes the factors that have hindered its progress. It will also look at the policies and reforms that need to be implemented for natural gas to attain its assigned role in the country's energy chain.

Evolution of the Indian Gas Sector

Till the early 2000s, the demand for gas was dominated by the power, industrial, and particularly the fertilizer and petrochemical sectors, termed as non-energy sectors, where gas is used as a feedstock. But as the demand for power and fertilizers increased, India's domestic output could not meet the growing demand and a liquefied natural gas (LNG) contract was signed with Qatar. Although various Indian governments have expressed their support to increase the gas share in the country's primary energy basket–driven by optimism over discoveries in the deep waters off the eastern coast of India in 2002 –and some technical experts stating that India could become a natural gas surplus country, the overall share of gas has been stagnating between 6% and 7%, barring a brief increase to 10% in 2010. This was due to the falling domestic production, short-sighted policies including subsidization and price regulations (Boersma, Losz, and Ummat 2017), and the high price of imported LNG, which made it difficult for the end-users to pay for gas-fired power generation or as a feedstock. Finally, the inadequate distribution infrastructure inhibited the increase of demand for gas in other sectors (Amanam 2017).

The 2015 Paris Agreement, which set goals, albeit voluntary, for countries to cut their carbon emissions to **limit global warming** to well below 2°C, **preferably to 1.5**°C, compared to the pre-industrial levels, contributed to re-set the gas policy in India (United Nations Climate Change n.d.). Although it was stated that renewable energy would be the focus in augmenting power generation efforts, it was acknowledged that fossil fuels would retain their space for decades as well. But given that natural gas produces approximately 25% less CO_2 than petrol, 27% less than fuel oil, 30% less than crude oil, and 45% less than coal (GECF n.d.), a shift from coal to gas power plants as well using it as a potential alternative to petroleum products in the transport sector is seen as a key strategy to support the goal of cutting emissions. In fact, by serving as a bridge fuel, natural gas is seen as an essential factor towards achieving the Sustainable Development Goals under the Paris Agreement. Thus, to increase the share of natural gas in India's overall energy basket, a number of issues discussed further need to be addressed.

Supply Bottlenecks

Despite the 'outstanding achievements' in India's energy sector, particularly in power generation, the IEA in a review of the country's energy policy says that the country still faces challenges of a magnitude and character unseen in any IEA member country (IEA 2020c; Forbes 2020).These include both supply and demand issues, given that creating a gas-based economy entails an increase in the share of gas consumption in each sector.

The first challenge that needs to be tackled is ensuring adequate supply. Out of the total available supply, more than 52% comes from imports. However, domestically produced gas is reserved for the priority sectors, like CGD networks for industrial consumption, CNG for transport, and PNG for residential segments, besides for power generation, fertilizers, and LPG. Consumers that are not in the priority sectors use more costly imported re-gasified LNG. Moreover, upstream companies engaged in exploration and production (E&P) cannot sell in the export market, ostensibly until India attains self-sufficiency.

In 2019-20, India consumed a total of 64,124 mmscm of natural gas, up from 60,798 mmscm in 2018-19, whereas domestic production was only 30,257 mmscm (in 2019-20), with the balance being imported (Sharma 2020). According to Petroleum Secretary Tarun Kapoor, the plan is to rely primarily on domestic natural gas, particularly from the east coast basin, and make up the balance through imports to facilitate India's energy transition to cleaner fuels. However, with the clear preference for domestic production, the output would have to grow at an unprecedented rate to meet the demand.

But, as Table 1 indicates, India's gas output has been stagnating and even declined since 2003. The production during 2019-20 was recorded as the lowest in at least 18 years, and the production from fields operated by private players and joint ventures declined by 34% (Abdi 2020).

TABLE 1: India's domestic natural gas production from 2002 to 2020

Financial Year	Natural Gas Production (BCM)	% Change
2002-03	31.38	
2003-04	31.96	**1.84**
2004-05	31.76	**(0.62)**
2005-06	32.20	**1.38**
2006-07	31.74	**(1.42)**
2007-08	32.41	**2.11**
2008-09	32.84	**1.32**
2009-10	47.49	**44.61**
2010-11	52.21	**9.93**
2011-12	47.55	**(8.92)**
2012-13	40.67	**(14.46)**
2013-14	35.40	**(12.95)**
2014-15	33.65	**(4.94)**
2015-16	32.24	**(4.19)**
2016-17	31.89	**(1.08)**
2017-18	32.64	**2.35**
2018-19	32.87	**0.70**
2019-20	31.17	**(5.17)**

Source: PNG Statistics

Several factors have contributed to the production patterns mentioned in Table 1. Debasish Mishra, Partner, Lead-Energy, Resources and Industrials at Deloitte India attributed the declining production to the 9-year long gap in oil and gas fields auction in the pre-Hydrocarbon Exploration Licensing Policy (HELP) regime (ET Energy World, 2020) (Bilal Abdi, "India's natural gas production falls 14% in March as demand dries up, 2019-2020 production lowest in 18 years", April 23, 2020)

It was noted that the impact is now being felt, given the long gestation period between discovery and market delivery. A former chairman of a large Indian oil producer said that apart from the current COVID-induced drop in the demand, other issues responsible were protests and *bandhs* against privatization of PSUs such as BPCL, maintenance and up-gradation activities in some oil and gas onshore and offshore fields, and less off-take by power producers as well as gas consumers (Abdi 2020).

In 2003, the government began importing gas in the form of LNG to meet the growing demand. But this only surged following a collapse in LNG prices in 2014 and the emergence of new capacity coming on stream in Australia, the USA, and Russia. All these countries now supply spot-based contracts to India. The drop in the international LNG prices led the government to push the consumption of gas in India and also helped in meeting the shortfall arising from the slowdown in domestic production. As of now, there are six operational re-gasification terminals in the country – three in Gujarat, two in Kerala, and one in Tamil Nadu. The terminals have a capacity of around 38.8 million tonnes per year with a re-gasification capacity of around 140 million metric standard cubic meters per day (mmscmd) (MoP&NG n.d.a), up from 21.7 million metric tonnes per year (mt/y) in 2018. Four more terminals are being constructed – two in Maharashtra, and one each in West Bengal and Odisha, while one (in Dabhol) in Maharashtra is being expanded, taking the total capacity to 59.1mt/y by the end of 2021 (Forbes 2020).

India has yet to establish cross-border pipelines, which is long pushed by various domestic and foreign entities. Although there are hopes that the Turkmenistan–Afghanistan–Pakistan–India (TAPI) project will be completed eventually, the focus is more on augmenting LNG receiving terminals, which leads one to believe that LNG is the preferred option to imported piped gas from across the border.

Some other issues that impinge on the sector include the inflexible nature of the international gas market and supply contracts that make it difficult for importers to negotiate better terms during volatile periods, problems in associated sectors that impact the role of gas, and domestic and international politics.

Demand challenges

A major driver for the augmentation of gas in the country's energy basket is the goal of cutting oil imports by 10% by 2022 (MP&NG n.d.a). Moreover, to meet its pledges under the Paris Agreement, apart from ramping up its renewable energy ambitions, India is looking at gas as an alternative to coal-based generation to meet the growing electricity demand. Notwithstanding the effect of the pandemic, the primary energy demand in India is projected to double by 2040 (Business Standard, 2021). Thus, natural gas and coal will be required to manage the intermittent generation from renewable energy sources as well as provide synchronous generation for grid stability in India.

According to a joint study by Smart Power India (SPI), NITI Aayog, and the Rockefeller Foundation launched in October 2020, despite almost 100% electrification, only 55% of the customers were satisfied with the quality of their electricity supply. The study mentioned that the power quality was ridden by voltage fluctuations, with only 31%reportedan average power cut duration of not more than 1hour per day (The Economic Times 2020d).

In its quest to increase the demand for gas, the government is augmenting the gas pipeline networks, including pipelines from re-gasified terminals to the city gas network and the CGD network. With the addition of 17,000km of gas pipelines being laid in the eastern part of the country to connect gas sources with consumption centers, more than 70% of the population has access to the CBD network, up from less than 20% in 2014. The capacity of LNG import terminals was also raised to meet the rising domestic demand (The Economic Times. 2020e).

Furthermore, as LNG has emerged as a viable alternative and is comparatively environment-friendly for the transport sector, the demand is likely to rise. To provide a fillip to the development of an LNG-fuelled transport system, a thrust to build LNG filling stations along the golden quadrilateral has been initiated (MoP&NG n.d.a).

While the city gas infrastructure has contributed to an increase in the consumption of gas, the same cannot be said in the case of the power sector. According to some officials, there is no future for gas-based power plants in the country, partly because of low domestic supply of gas, high imported gas price, inability to compete with lower-cost fuels, such as coal and, more recently, renewable energy, and paucity of government initiatives. Currently, according to the power ministry data, the share of gas-based generation is 6.8%, with more than 14,000 MW of gas-based power plants lying idle. Even in the current low gas price regime, with the cost of gas-based power generated being equivalent to that from imported coal (Chatterjee and Srivastava 2020), there is no substantial improvement. The reason being earlier supply shortages led to low utilization rates and cost escalations of 50–75%. As a result, many of the plants are unable to service their debt obligations and are on the verge of becoming non-performing assets. According to the submissions made by the Power Ministry, 31 gas-based power plants have been declared stranded, of which one belongs to the central government, six belong to the state governments, and 24 gas-based power plants belong to the private sector (Abdi 2019).

Hence, to realize the goal of a 15% share for gas in the primary energy basket, the impediments have to be addressed and reforms are initiated.

Reforms initiated

Before 1999, the national oil companies had a monopoly over the oil and gas sector, and as the demand for oil and gas increased, the supply could not keep pace. There was an urgent need for reforms in the upstream sector, mainly to increase domestic production and manage the pricing of gas (and oil) across the value chain. Therefore, to increase the output as well as attract investment and state-of-the-art technology into the upstream sector, the New Exploration Licensing Policy (NELP) was adopted in 1999, under which E&P contracts were awarded within production-sharing agreements. The process comprised nine rounds of biddings, in which both domestic and foreign firms were given equal opportunities and permitted 100% foreign direct investment in exploration activities. However, despite the reforms, 71.5% of the production continues to be from state-owned companies, with the remaining 28.5% from private/joint venture companies.

It was only from 2015 that significant changes in the government policies regarding oil and gas have been undertaken. The government approved 69 marginal fields/discoveries for offer under the Discovered Small Fields Policy within the new regime of Revenue Sharing Model to unlock in-place oil and gas reserves of 40 million tonnes of oil and 22 billion cubic metres of gas over 15 years. Six months later, in March 2016, the NELP contracts were superseded by the Hydrocarbon Exploration and Licensing Policy (HELP), in which a revenue-sharing mechanism, as against the earlier production-sharing format, was adopted. The policy provides marketing and pricing freedom for any hydrocarbons produced. In addition, HELP follows a uniform licensing policy under which one license covers E&P of all hydrocarbons, including oil, gas, coal-bed methane (CBM), shale gas/oil, and gas hydrates. Furthermore, the Open Acreage Licensing Policy (OALP), which is one of the main facets of HELP, allows upstream firms the flexibility to choose the blocks to carry out relevant activities.

To further incentivize domestic investment and production in the upstream sector, a National Seismic Programme was launched in October 2016 to review the unappraised areas in all the sedimentary basins where little or no data was available. Under the programme, approval was given for conducting 2D seismic surveys for data acquisition, processing, and interpretation covering thousands of kilometres. Furthermore, in July 2017, an E&P data bank and a National Data Repository with state-of-the-art facilities and infrastructure for preservation, upkeep, and dissemination of data were set up to enable access to quality data for future exploration and development.

In April 2017, the government introduced a policy framework for early monetization and marketing and pricing freedom of CBM producers. A year later, a policy framework for E&P of unconventional hydrocarbons was also introduced, whereby existing contractors under the NELP and pre-NELP regimes and nomination blocks were allowed to tap unused unconventional hydrocarbons such as shale oil/gas and CBM, subject to certain conditions (MoP&NG n.d.b).

More attractive fiscal and contractual incentives for E&P activities were also introduced in 2019 in unexplored basins in Category-II and III basins to encourage upstream companies to enter new and unexplored areas (MoP&NG n.d.b).

On October 27, 2020, Oil and Natural Gas Corporation Limited (ONGC) issued the expression of interest notice to offer 15-year production-enhancing contracts to outside contractors for a number of 'mature', mainly onshore, fields in an attempt to reverse the declining output. As per the notice, tariffs will be paid in USD per barrel foroil and USD per metric million British thermal units (mmBtu) in case of gas for any incremental amount produced. Although the names of the fields on offer were not mentioned, they are largely believed to be in Assam and Gujarat – ONGC's oldest finds (The Economic Times 2020f).

Finally, in June 2020, the country's first online delivery-based gas trading platform –India Gas Exchange– was launched. It is expected to play a major role in developing the gas market, as well as attracting foreign investment and technology. Through the digital trading platform, gas buyers and sellers can trade both in the spot market and forward market for imported natural gas across three hubs including Dahej and Hazira in Gujaratand Kakinada in Andhra Pradesh. Imported LNG would be re-gasified and sold to buyers through the exchange, thereby removing the requirement for buyers and sellers to find each other.

However, while the gas exchange will provide the impetus towards transparency in pricing through e-bidding, a lot more is still required for taking the Indian gas market to the level of maturity seen in developed countries. As of now, the reforms already initiated will, at best, be an intermediate step, while a fair and transparent regulatory system along with free pricing mechanism will have to be set up for a fully developed sector. with the requisite regulatory mechanisms and free pricing system that can be formed.

Pricing Mechanism

One of the biggest challenges for the hydrocarbon sector is the skewed pricing mechanism being followed over the years. The mechanism has contributed the most towards the under-development of the domestic gas market. Several committees came into being to work out an effective pricing framework that would be acceptable to producers as well as customers. As a result, a multiple and non-market-driven pricing mechanism has prevailed, which failed to strengthen the Indian gas market. Different prices were set for different sectors. For example, the power and fertilizer sectors get subsidized prices, and certain regions such as the north-eastern states get gas at relatively cheaper prices compared to other parts of the country. This triggered the dis-incentivizing of investments into the sector, leading to limited participation from international companies who have access to the technology that is crucial for difficult deep-water E&P activities.

With consistent demand from E&P firms, the government introduced a 'free' gas pricing mechanism for production from small and marginal blocks, difficult high pressure/ deepwater blocks, and the newly bid blocks under the Hydrocarbon Exploration Licensing Policy (HELP). However, the pricing and marketing of gas from the exploration blocks assigned before 1997 and those under the New Exploration Licensing Policy (NELP) in 1997 are still regulated and based on a 2014 government-set formula. The formula takes average rates of the previous year from the global trading hubs namely, the US-based Henry Hub, Canada-based Alberta gas, the UK-based National Balancing Point (NBP), and Russian gas, and is enforced with a quarter's lag for 6months. With this formula, producers can charge market rates for gas from the deep-sea and other difficult fields, as long as they remain below the government-prescribed ceiling which is linked to the prices of alternative fuels. Consequently, gas prices are set at low rates – the most recent cut being by 25%–which fall below the cost of production for many fields. In this scenario, producers become critical as it adversely impacts their profits as well as investments. Thus, domestic production has not picked up as was expected, which lead to a substantial fall in the output in FY20. This pushed up relatively expensive imports of LNG (The Economic Times 2020g), both in terms of long-term contracts and spot purchases, which together currently accounts for 52% of the supply (MoP&NG n.d.a).

The government's rationale for the low price is to pass on the cuts to buyers under power purchase agreements to reduce the cost of gas-based power generation in the hope that it will boost off-take. But critics say that this will not achieve the desired result, at least in the power sector, due to priority given to renewable power plants, while demand remains low due to lower growth rates (Financial Express 2021). No doubt, the gas price cut may benefit the fertilizer sector by boosting profitability and more usage. Moreover, CNG companies may also benefit provided they pass on the lower prices to the customers in the transport and residential sectors, making these fuels more competitive than liquid fuels and LPG, respectively.

Recently, the petroleum minister hinted that more market-driven reforms in the gas sector are being contemplated to support the profitability of upstream producers. Given that the current pricing mechanisms driven by the global benchmarks which are lower than their Asian counterparts, there are reports that India may be considering linking its domestic natural gas price to an Asian benchmark. However, the pricing reforms are expected to be completed slowly (The Economic Times 2020g).

Are reforms half-baked?

To increase the share of gas in the country's primary energy basket from the current 6.5% to 15%, its consumption/demand should improve from the current level of 153 mmscmd to 611 mmscmd by 2030. This requires reforming the domestic gas market both in terms of supply as well as demand. Though, since 2015, several reforms were introduced in the sector and many policies were acknowledged as the major steps towards increasing the share of gas in the economy, many industry experts believe that they do not go far enough. To start with, the pricing reforms only extend to the new fields; hence, unless they are extended to production from old or government-allocated fields, the share of domestic gas in the basket will remain minuscule. The recent cut in prices by 25% would cause massive losses to companies like ONGC. Therefore, to construct a level playing field, prices should be freed up across the board or a floor pricing that is based on import parity should be introduced across the board.

In the case of Gas Exchange, its eventual viability depends largely on liquidity and volumes – when there is a large number of buyers and sellers. However, by keeping domestic gas out of the exchange, availability is not sufficient. Moreover, the price disparity with respect to domestically produced gas versus imported LNG continues is also a challenge, with buyers demanding cheaper gas. If domestic gas is introduced on the (gas) exchange, it will go a long way in reducing the price volatility as well as demands made to the government to allocate cheaper gas. The government's concern, however, is that introducing domestic gas in the exchange could see an increase in prices, which would affect the downstream consumers, and would in turn deter a rise in demand eventually.

With regard to the upstream pricing reforms, although there is room to increase the price of gas without affecting consumption, the industry has also been demanding the inclusion of natural gas in the goods and services tax (GST) regime. The inclusion would lead to the removal of various value-added taxes charged by states and reduce taxes for the sectors such as power and steel (Jacob 2020).

Similarly, the new rules for city gas distribution networks, introduced by the Petroleum and Natural Gas Regulatory Board (PNGRB) in September 2020, have raised several concerns that it would be discriminatory for different players. Existing transporters allege that the proposed regulation for open access does benefit those who have already invested heavily in the sector. Moreover, they are bound by the policy to supply to economically unviable segments, such as the fertilizer and industry sectors, leaving new entrants to cherry-pick more lucrative sectors. The new guidelines also lack clarity on the issues including the determination of the capacity based on geographic area/region and the number of third-party competitors allowed to sell in that area (Pathak 2020).

Finally, to facilitate a quicker push towards a gas-based economy, the tax regime on gas should be re-examined. The government has so far been reluctant to bring hydrocarbons including diesel, petrol, CNG, PNG, or natural gas under the rationalized GST as it prefers to retain the flexibility to meet its fiscal goals. However, a relatively lower GST rate for gas would incentivize consumers to increase demand. It is also expected that controls over gas pricing will gradually be phased out over the next three years, bringing the Indian gas sector closer to developing as a free and market-driven one. However, there is a lot of work still to be done to make the transition a success.

Role of Natural Gas in Sustainable Energy Future

Although the National Democratic Alliance (NDA) government is doing all it can to augment the use and supply of natural gas in the country's economy, the question is when the world's focus is on renewable resources and other green fuels, will the gas be redundant over the next few years? The latest resource that has captured the interest of several governments is hydrogen – the most abundant element in the universe. A consortium of European countries including Norway, the Netherlands, and the UK, is planning to construct a 10-GW wind farm in the North Sea dedicated to the electrolysis of water to produce green hydrogen. The cracking of water will be attained by using other fuels, including natural gas, coal, and renewables.

Even in the USA, while natural gas continues to be used substantially, the plan is to utilize 'cleaner' gas. These include carbon capture, use, and storage (CCUS), tightening up methane leaks from gas fields, and enriching natural gas with hydrogen to improve burn and reduce carbon load. Moreover, surplus wind and solar power, that is, the amount which is not used for independent power production, will also be used for hydrogen production by electrolysis (King 2020).

The potential of using hydrogen as a cleaner fuel alternative has been around for a while. However, it is considered to be prohibitively expensive as a huge amount of electricity is required for the electrolysis process.

Typically, hydrogen can be produced in one of the three ways, i.e., from fossil fuels (grey hydrogen), through CCUS application and fossil fuels (blue hydrogen), or by using renewable energy (green hydrogen). In the case of green hydrogen, electricity generated from renewable energy is used to split water into hydrogen and oxygen (Alternative Fuels Data Center, US Department of Energy n.d.). This is by far the cleanest and perhaps the most expensive method of producing hydrogen at the moment. The majority of the hydrogen produced in India is through fossil fuels and is used primarily in the chemical and petrochemical sectors.

Therefore, as the price of natural gas along with renewable is declining, the economics may become more feasible. According to recent research, solar power used to run the electrolysers for splitting water can run six times higher than the natural gas-driven steam reforming process, wherein high-temperature (700°C–1000°C) steam is used to produce hydrogen (Temple2020).

Hydrogen is also seen as a potential alternative fuel in the transport sector. On October 20, 2020, the Delhi government introduced 50 buses running on hydrogen spiked compressed natural gas (H-CNG) in a six-month pilot project. The buses run on a new technology patented by the Indian Oil Corporation Limited that produces H-CNG (18% hydrogen in CNG) directly from natural gas without undertaking expensive conventional blending, making it 22% cheaper. The fuel ensures a 70% reduction in carbon monoxide emissions than CNG and a 25% reduction in emissions from hydrocarbons. Nonetheless, this is being considered only as a stop-gap arrangement, until a cost-effective variant of green hydrogen-blended fuel is discovered.

According to a study by Volkswagen, roughly a hydrogen-run vehicle achieves an energy efficiency rate of 25–35%, depending on the model. Over time, the hope is that economies of scale will be attained, making hydrogen an economically viable alternative (Goldar and Dasgupta 2020).

Nonetheless, despite the excitement over hydrogen, some challenges will need to be overcome. For example, hydrogen has a third of natural gas' energy content, thereby requiring more hydrogen to be used to produce the same amount of energy. In the case of green hydrogen, derived from renewables, the volume required will be even more. Also, pipelines, storage, compressors, and pumps will have to be modified to enable the use of hydrogen.

Conclusion

No one can predict with certainty how COVID-19 will proceed, and whether further 'waves' will occur, which will have fallout on national economies and indeed the global economy. In turn, this will impact the energy demand and much will depend on the price of various fuels – traditional as well as renewable.

As has been witnessed, the fall in demand for oil and gas during the lockdown had resulted in a crash in prices. (has already been mentioned in the first para) Many economies will opt for cheaper fossil fuels, albeit for smaller volumes. For others, the carbon content factor will prevail to some extent, and the diminished demand will allow renewals to satisfy the demand to some extent. But for countries like India, which is showing a gradual but certain growth trajectory, the outlook for energy, and particularly natural gas, is expected to be optimistic. (refer to the number of LNG receiving terminals being constructed) Nonetheless, there is no doubt that the success of a sector is largely policy-driven. A perfect example is the solar energy sector, which staggered till 2014 when the NDA government gave it the requisite policy support and environment to flourish. There is, thus, hope that with the government's recent pronouncements on developing a gas-based economy, a similar environment will be created to provide the fillip required to develop the gas market. To that end, several reforms have been announced in 2020 to facilitate more domestic production as well as free market pricing for gas.

Unfortunately, as has been the case in some other sectors, the current reforms have been piecemeal. Take the upstream reforms, for example. The free market pricing provided to E&P firms to encourage more investment into production has left out the majority of India's natural gas discoveries as they apply only to the newly discovered fields. The rationale for not holistically freeing up prices is the concern that higher prices will add to the cost of fertilizers and electricity. However, if producers like ONGC (state-owned firms) do not get to earn more profits, they will have fewer resources for investing in the sophisticated technology required to explore and extract more gas from difficult geological terrain. This will, in turn, see a further rise in more costly gas imports, which has already surpassed domestic production, thereby negating the goal of self-sufficiency.

Finally, the new pricing and marketing 'freedom' continues to be half-baked. The current administered pricing formula, which is based on the weighted average price of four global benchmarks and that too with a quarterly lag, will continue to be in force for production from existing discoveries awarded under the NELP and pre-NELP regime. On the other hand, full marketing and pricing freedom is granted to the discoveries under the OALP rounds which came on stream from February 2019. With the recent drop in spot LNG prices, the government imposed a massive 25% cut in the administered price, which will be far lower than production costs from the older nominated fields, and which will further de-incentivize the production accretion from older fields.

The good news, however, is that the government has set up a committee to look at further pricing reforms, including the price formula for domestic natural gas to encourage investment in the sector. This could entail providing a price flooring and/or changing the current four-tiered pricing formula.

While the reforms continue to cause concerns in some gas-based sectors, they have brought some cheer to others, evidenced by an uptick in demand. At the end of August, higher demand from fertilizer plants, refineries, and power plants helped the natural gas demand recover to pre-COVID-19 levels with consumption in July 2020 was just 2% lower than the last year (Chaudhury 2020).

To further broaden the demand for gas, Petroleum and Natural Gas Minister Dharmendra Pradhan recently called for a campaign to bring greater awareness about the benefits of gas in the transport sector (MoP&NG n.d.c). Early reports from the recently established gas exchange indicate that there are takers in the non-priority gas consumption sectors, even for more costly imported LNG. Moreover, the success or failure of a sector depends to a large extent on a concerted policy push, and the government has, time and again, enunciated its determination to push for greater consumption of gas in the country's primary energy basket.

Nonetheless, the Indian gas market continues to suffer from price distortions, which is a major disincentive for both producers and buyers as it discourages investment on both sides. Time and again, a new gas pricing mechanism has been suggested. The rating agency ICRA has said that the production of natural gas will remain a loss-making proposition because of low government-dictated prices (Business Today, 2021). A 'gas price index' that will realistically reflect the market price of wholesale gas in India would be a good beginning. Not only would it assist in reducing the premium on imported LNG due to the price indexation to international fuel markers, but would also provide the correct inputs for investment requirements in the gas value chain and facilitate efficient usage.

Moreover, new technologies in plants, both with and without carbon capture and sequestration (CCS) mechanism, are emerging. One example is the Allam Cycle, which uses high-pressure oxy-fuel to run a supercritical CO_2 cycle, uses less water, emits almost no carbon, and costs less than conventional plants (Roberts 2018). India should invest more in emerging technologies to resolve its energy-related challenges.

What is required, therefore, is a holistic approach to reforms as opposed to the current piecemeal approach across the energy chain. Recently, Mr Pradhan referred to gas as 'a fuel of the future', with cost and environmental benefits over other fuels. Only time and government support will see whether it would be feasible for gas to be a part of India's energy future or not.

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CHAPTER 4

Alternative Fuels for a Green Future – Challenges and Opportunities for India

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Abstract

Transport fuels employed for road, aviation, and marine sectors constitute a major portion of the total energy needs of a country. These fuels, presently, are mostly of fossil origin. India is unfortunately not blessed with crude oil resource and it imports more than 80% of crude oil requirements. The country, due to its rapidly increasing GDP, is experiencing the most robust growth in energy consumption. Therefore, increasing dependence on imported crude translates to worries regarding energy security.

Fossil-derived transport fuels are also responsible for major greenhouse gas (GHG) emissions, estimated to be around 24% of total GHG emissions. Therefore, fossil-derived transport fuels are major impediment to meeting our sustainable development goals (SDG). Global efforts, especially in the last two decades, have been focused on developing alternate, renewable non-fossil transport fuels having lower GHG footprints and meeting the criteria of sustainability, affordability, and which can be employed on a very large scale. The alternate fuels preferably need to be either liquid or gaseous so as to be quickly adopted in internal combustion engines (IC), which constitute almost whole of the transport system.

Bioenergy is one such option that meets the criterion of renewable, sustainable energy source, having much lower GHG footprints. With latest technological developments, bio-derived fuels are fast becoming affordable vis-à-vis their fossil fuel equivalents.

Biodiesel and ethanol have seen market maturity and these are being blended in fossil diesel and petrol by several countries including India. However, the feedstocks for these biofuels are country specific, from corn and soybean in West to sugar cane in Brazil. India has to support a very large population on comparatively smaller land area and thus our feedstock for biofuels has necessarily to be of non-food category. Ethanol, produced from sugar cane molasses, was introduced in India in the early 1990s as a blend fuel component for gasoline. Though the first biofuel policy envisaged blending up to 20% ethanol in gasoline, supply side constraints were encountered and the blending was less than 2–3% in gasoline pool. Pricing was another issue that did not encourage sugar mills to provide ethanol for fuel blending. Later the feedstock issues were looked into and a promotional pricing policy led to an increase in blending of ethanol in petrol to about 5.5%. However, to increase blending to 20% level, new production routes and feedstocks to ethanol and other biofuels are necessary.

Cellulosic ethanol from agricultural residue is one such option being explored to produce ethanol at large scale and the technology, though already commercial, is being perfected so as to bring down the costs of production. Biomass gasification to syngas and then to hydrocarbons is yet another option of producing diesel and aviation fuel.

Technology options are now available to produce liquid/gaseous transport fuels from agricultural residues, forest, and dairy waste and MSW (municipal solid waste). The transport sector is undergoing rapid changes and alternative fuelling options are emerging. Electric mobility and fuel cell powered by hydrogen will see wide deployment in the next two to three decades.

This chapter will cover the present Indian requirements and future projections till 2040 for major transport fuels. Development cycle of various biofuels in India and globally, and technological advancements to make these fuels affordable will be discussed. GHG impact factors and life cycle analysis of few fuel types and policy support measures will be examined. The Indian government's efforts to provide assured market, support price, and other policy issues will be also discussed.

Introduction

At the beginning of the 1970s, OPEC (Organization of the Petroleum Exporting Countries) announced controlled reduction in oil production, and therefore the price of petroleum crude increased exponentially causing an energy crisis (Zhang 2013). This event created the beginning of interest in alternative fuels. Later it was realized that fossil fuels are also responsible, to a large extent, for climate change and this focused more interest in alternative energy sources (Lal 2005). Renewable energy sources that are sustainable, provide energy security, and also curtail GHG emissions are being promoted in most countries.

According to IEA (International Energy Agency) report of World Energy Outlook 2018, the transportation sector, which consumed 32% of the produced oil in 2017 (IEA 2018), was responsible for 42% of the global CO2 emissions. Diesel, gasoline, and aviation kerosene constitute most of the fossil fractions used in the transport sector and these two were first to be targeted for part/full replacement by biofuels, which have lower GHG footprints.

Bioenergy and biofuel technologies can be classified either as per classical TRL (technology readiness levels) or preferably according to four development stages. The first stage is prototype where both concept and design of technology exist and the product is ready for second stage, which is demonstration. Synthetic hydrocarbons, algal-based biofuels, and hydrogen-based transportation are a few examples. Third stage of technology development is early adoption where economic benefits are less but private sector starts investing. Cellulosic ethanol falls under this category and improvements in technology occurs. The last – the fourth stage – is when technology reaches maturity and large-scale penetration takes place in the market. Conventional ethanol/biodiesel and compressed biogas (CBG) through anaerobic digestion is an example of mature technology.

Governments need to support the first three phases by investing in research and development (R&D) and in large pilot plants. It needs to create assured market for phase 3 and phase 4 products of advanced biofuels, for initial few years, till these reach market maturity and production scales on multiple commercial scales begin. The example most suited where the government intervention successfully matured a technology in alternate energy is solar PV and wind power. Like several other countries, the Indian government supported the first phase of solar power by heavily subsidizing cost for the purchase of power by distribution companies and also creating assured market by way of renewable power obligations. A few initial years of hand-holding brought down solar PV production costs with advancement in technology, proper supply chain, and economy of scale. At present, solar PV is competing with and is cheaper than thermal power. Similar trajectory is required for biofuels, especially advanced biofuels from agricultural residues.

Ensuring Indian citizens access to electricity and clean cooking has been at the top of the country's social and political agenda. Around 750 million people in India gained access to electricity between 2000 and 2019, reflecting strong and effective policy implementation. The Government of India has also made significant progress in reducing the use of traditional biomass in cooking, which is a very inefficient way of using biomass and is also cause of indoor air pollution. At present, subsidized LPG, partly imported, is being provided for household cooking. Government of India plans to set up 5000 CBG plants to make available 15 MT (million tonne)/year of green gas to replace fossil-derived LPG.

Today, most biofuel supplies come from conventional ethanol and biodiesel production processes that were developed decades ago, though recent advances have improved the performance of plants and lowered costs. A growing share of biofuels now comes from advanced technologies, notably hydrotreated vegetable oil (green diesel) produced from waste feedstock, which accounted for 8% of biofuels production in 2018. This green diesel is a drop-in fuel without problems of blending. The investment in lignocellulosic ethanol production, which makes use of farm and forestry waste, has not progressed as expected. The process of converting lignocellulosic materials to ethanol is more complex than that used to convert starch and sugars into ethanol, and the future of this type of biofuel needs R&D to reduce costs at every stage of the lignocellulosic ethanol production. R&D in enzymes, which are used in hydrolysis of cellulose to monomeric sugars and add to overall cost, has already given good results and the cost of enzyme dosage has gone down by a factor of 10 in 5 years. US DOE supported private enzyme companies for this R&D. Proper supply chain for biomass and utilization of utilities from the existing first-generation ethanol plant are yet another cost reduction area. Integration as biorefinery with production of biochemicals along with ethanol is being practised and has a substantial effect on reducing the cost of bioethanol.

Advanced biofuel feedstock can be free from sustainability concerns that are existing for feedstock of first-generation ethanol and biodiesel. Sustainable biofuels can be produced from residues and wastes from the agriculture, forestry and food industries, or from non-food crops grown on marginal land. The possible routes to biofuels from biomass advanced biofuels are shown in Figure 1. Advanced biofuel technologies include cellulosic ethanol, biomass-to-liquid (BTL) thermochemically produced fuels, hydrotreated vegetable oil (HVO) biodiesel from wastes and residues, and hydro processed esters and fatty acids (HEFA) biojet fuel from wastes and residues. BTL and HVO/HEFA are technically drop-in biofuels.

While cellulosic ethanol from agricultural waste, HVO using oilseed, and used cooking oil/animal fats are in commercial phase, conversion of biomass directly to liquid fuels is in demonstration phase in which even MSW can be used to produce liquid fuels via gasification.

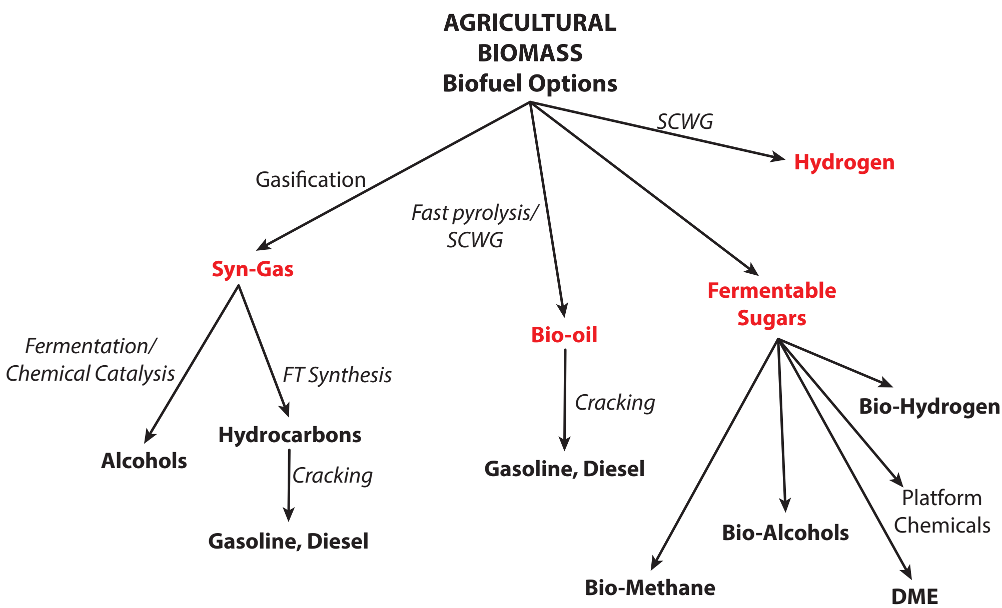

FIGURE 1: Biofuel options from biomass

Bioenergy Projections

Bioenergy has a central role to play in reducing carbon emissions from the energy sector. An important advantage of bioenergy is that it can be converted into energy forms that are compatible with existing energy technologies that rely on the combustion of fossil fuels in the existing internal combustion engines. The liquid biofuels can be stored, transported, and dispensed just like the corresponding fossil-derived gasoline and diesel. Biofuels can be used as feedstock in the chemical industry as well. Just like the biggest advantage of solar PV is that it can use the existing transmission infrastructure, biofuels can be transported by existing fuel pipeline infrastructure.

Around 60% of final bioenergy use (and 40% of primary bioenergy use) is today in the form of the traditional use of solid biomass for cooking, especially in the third world and in emerging economies (IEA 2018). Emission from burning of household raw biomass leads to indoor air pollution and is harmful for human health. The UN mandate aims for reduction in the traditional use of solid biomass by almost 90% over the next 10 years, which requires a steady increase in the efficient use of biomass in the form of liquid or gaseous biofuels. The bulk of bioenergy use in 2070 is for making transport biofuels for power and heat generation. However, the real impact of GHG reduction by biofuels will be observed if the carbon dioxide produced during the production process is efficiently captured by suitable CCUS technologies.

Biofuels – Global Scenario

Liquid biofuels derived from sustainable biomass can provide a lower carbon alternative to conventional petroleum-based diesel and gasoline. In the last decade, biofuels have seen constant growth and data by Pike research indicates a CAGR of 8.4% in the last 10 years (Figure 2). Almost whole of this biofuel market was primarily conventional first-generation ethanol and vegetable oil-based biodiesel. With conventional biofuels, careful attention must be paid to sustainability concerns. These include competition for agricultural land with food crops and potential direct and indirect land-use change impacts, which can adversely affect biodiversity.

Conventional biofuels are still the most used biofuels and the liquid biofuels for the transport application met 3.5% of all transport liquid fuel demand in 2019 (about 97 Mtoe). IEA estimates that by 2040 liquid biofuel would rise by 3.8 times the current use and reach to about 400 MT/year, which represents about one-quarter of transport liquid fuel production by 2040 (IEA 2018). Much of the biofuel in 2040 is expected to be advanced biofuel from biomass through biomass-to-liquid technologies using thermos and biochemical routes. Biofuel plants will also be coupled with carbon dioxide capture and utilization (CCUS) technologies making a very substantial GHG emissions reduction.

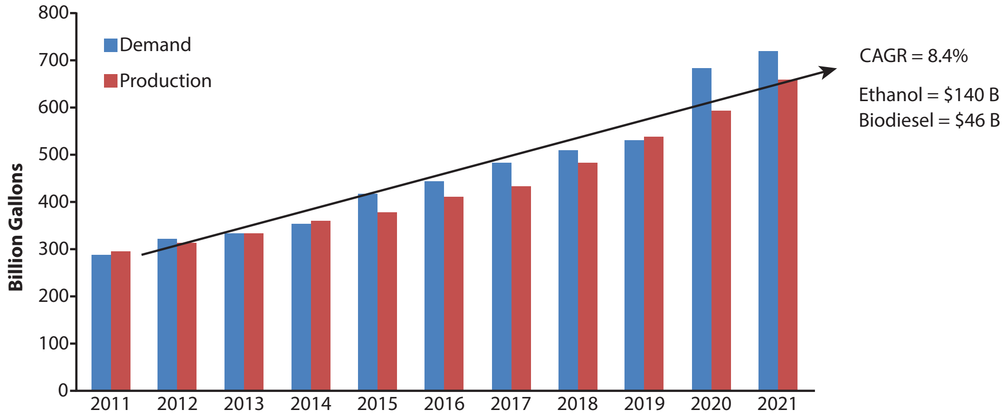

FIGURE 2: Growth of biofuels

Cellulosic Ethanol

Ethanol produced from biomass, corn in the United States, and sugar cane in Brazil is the most widely used biofuel in the transportation sector worldwide. The annual world production of bioethanol almost doubled in 8 years (13.0 billion gallons in 2007 to about 25.6 billion gallons in 2015), most of which came from the United States and Brazil (Sawin, Seyboth, Sverrisson, *et al*., 2016). Bioethanol from starch (corn) and sugar is termed as first-generation ethanol and the technology for large-scale production is mature. The main disadvantage of first-generation ethanol is that it is derived from food crops and this raw material can be limited for countries like India and China, which need to feed large population on relatively limited agricultural land.

Cellulosic biomass, or lignocellulose, is considered the most suitable feedstock for producing bioethanol due to its large availability, low cost, and it does not compete with food production as sugar/starch feedstocks do. Therefore, cellulosic ethanol, called second-generation ethanol, has gained tremendous attention in the last decade (Zhai, Hu, and Saddler, 2016; Lynd, Liang, Biddy, *et al*., 2017). The cellulosic ethanol can be produced from agricultural residues (rice straw, cotton stalk, forest waste, etc.) and these materials have approximate composition of 30–60% cellulose, 20–40% hemicellulose, and 15–25% lignin. The technology involves steps such as pre-treatment, enzymatic hydrolysis, and fermentation and involves solid–liquid separation. Therefore, even when the cost of lignocellulose is lower than that of the sugar/starch crops, the production cost of cellulosic ethanol is too high to be competitive (Lynd, Liang, Biddy, *et al.*, 2017; Dale, Anderson, Brown, *et al.*, 2014). Continuous R&D efforts have resulted in reduction of costs, especially of enzymes (Zhai, Hu, and Saddler, 2016; Lynd, Liang, Biddy, *et al.*, 2017; Dale, Anderson, Brown, *et al.*, 2014), but still more efforts are required to improve the capital-intensive steps of pre-treatment and complete fermentation of xylose.

Cellulosic Ethanol Production Process

Lignocellulosic feedstocks include agricultural wastes (corn stover, wheat or rice straw), sugar cane bagasse, wood (hardwood or softwood), grass, municipal waste, energy crops, and so on (Kumar, Tabatabaei, Karimi, and Horváth, 2016). Lignocellulose is composed of lignin, polysaccharides such as cellulose and hemicelluloses, ash, and so on (Van Dyk and Pletschke, 2012). The cost for storage, transport, and collection of low-density lignocellulosic feedstock (Balat, Balat, and Öz, 2008) is one of the major issues. The production process starts with the collection and transportation of lignocellulosic feedstock to the plant site. It is fed to a size reduction step by grinding and milling (Bilal, Asgher, Iqbal, *et al.*, 2017). The lower the size, the better is the subsequent conversion, but this step is energy intensive.

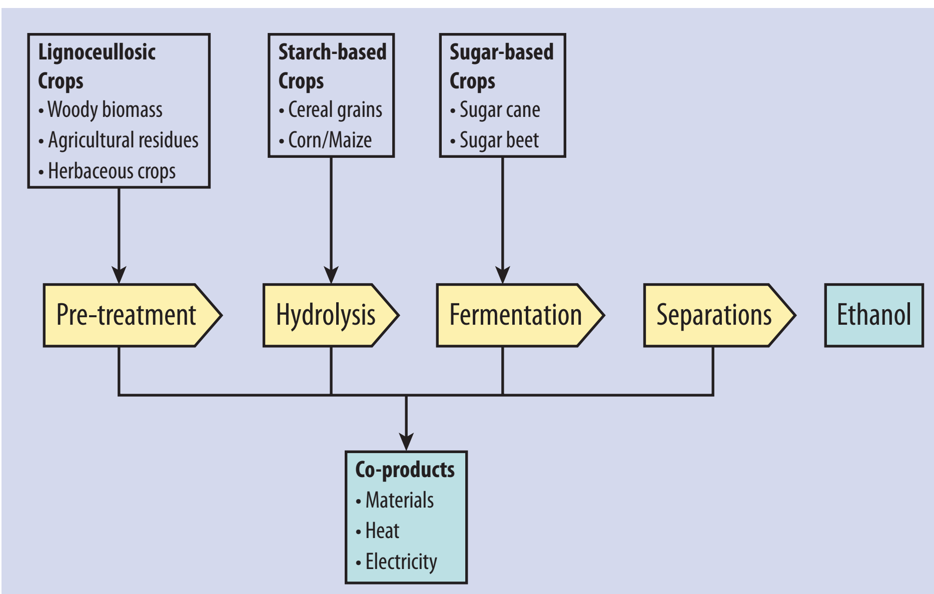

FIGURE 3: Ethanol production from sugars, starch, and lignocellulosic materials

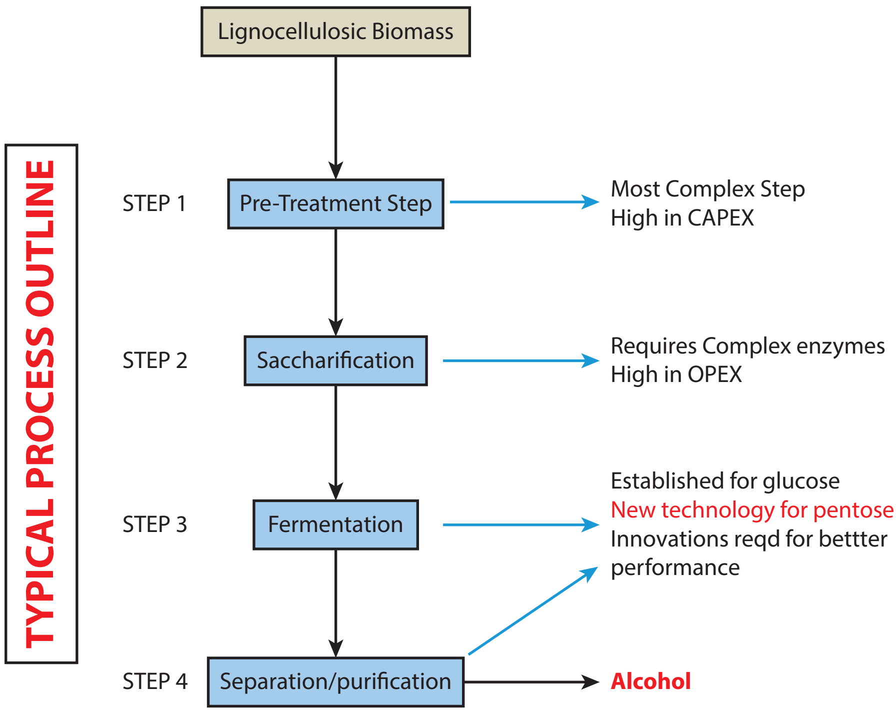

FIGURE 4: Major steps in the production of cellulosic ethanol

Ethanol produced from sugar cane juice/molasses needs only fermentation to yield ethanol while from starch (corn) the additional step of hydrolysis is required before fermentation (Figure 3). However, for lignocellulosic materials we need a step called pre-treatment before enzymatic hydrolysis and fermentation.

As shown in Figure 4, bioethanol production from lignocellulose typically comprises four major steps: (1) a pre-treatment step to expose polysaccharides, (2) an enzymatic hydrolysis step to break down polysaccharides to simple sugars, (3) a fermentation process where a yeast ferments sugars into ethanol, and (4) purification through distillation and drying to obtain fuel grade ethanol (Schwietzke, Ladisch, Russo, *et al.*, 2008).

Multiple pre-treatment technologies such as dilute sulfuric acid (DA), organosolv, ammonia fibre, and steam explosion (SE) have been developed (Mosier, Wyman, Dale, *et al.*, 2005). SE and DA pre-treatments are most commercially accepted and both hydrolyze a large portion of hemicellulose as well as disrupt lignin. The enzymatic hydrolysis of lignocellulose is the main reoccurring expensive step to produce feasible second-generation bioethanol. During enzymatic hydrolysis, cellulase and hemicellulase enzymes depolymerize cellulose and hemicellulose to C_6 sugars and pentoses, respectively.

Cellulases, enzymes required for hydrolysis, produced from *Trichoderma reesei* and *Aspergillus niger* are the most extensively studied (Nidetzky, Steiner, and Claeyssens, 1994). Some of the commercial enzymatic preparations are from Genencor, Novozymes. Novozymes enzymes have been used by several commercial plants and these have been offered to Indian cellulosic ethanol plants as well.

Department of Biotechnology (DBT) has been extremely active in supporting Indian R&D institutes to develop and commercialize cellulolytic enzymes suitable for cellulosic ethanol. DBT has mandated its centre of excellence to develop commercial scale enzyme technology. There has been very intense activity in India to develop its own cocktail of cellulase enzymes and several fungal candidates have been developed and a few scaled up to pilot level; however, none has been used for any commercial scale production. As is understood, for commercial plants being established by public sector oil companies, none of the Indian companies/institutes have submitted any interest. The technology suppliers have based their package on Novozymes enzymes.

Fermentation is the third step in the cellulosic ethanol process. In this step, sugars produced during enzymatic hydrolysis are converted to ethanol by yeasts. Natural adopted strain *Saccharomyces cerevisiae* for C_6 sugars and genetically modified yeast for C_5 sugar fermentation are generally used.

Zymomonas mobilis, a Gram negative, facultative anaerobic bacterium, has also been used for glucose fermentation and it has notable bioethanol producing capabilities that surpass yeast in titer. However, *Z. mobilis* cannot tolerate toxic inhibitors present in lignocellulosic hydrolysates such as acetic acid and various phenolic compounds and for this reason it is not used commercially.

While the fermentation of glucose is established and very efficiently done, the pentose sugars are not converted by natural organisms. Genetically engineered yeast for fermenting pentoses at productive yields is required (Jeffries and Jin, 2004). Ethanol broth undergoes distillation, adsorption, or filtration using molecular sieves or membranes to yield fuel grade ethanol that is about 99% pure (Cho, Park, and Jeon, 2006).

Global Scenarios of Second-generation Ethanol

The United States and European Union have struggled to expand and achieve commercial scales of production despite nearly a decade of policy support (Pavlenko, 2018). To date, the cellulosic ethanol is just a little fraction of ethanol produced by the first-generation biofuel industry. Many of the initial second-generation biorefineries are struggling due to a combination of delays and cost overruns, which are often attributed to pre-treatment difficulties and the targets set for cellulosic ethanol have not been met.

Supporting the advanced biofuel industry would require a substantial combination of capital grants, production subsidies, and long-term procurement contracts. The technology for cellulosic ethanol is still evolving, sustainable supply line of feedstock is being established, and moreover the cost of conversion is higher compared to first-generation biofuels. However, the silver lining is the continuous improvement in technology, which is seeing reduction in both capital expense and operating expenses. The Indian government has decided to support 12 cellulosic refineries. The first four of these are based on the technology developed by India (Praj Industries, 2019) and are of the scale comparable to the commercial scales seen in the USA and EU. The nameplate capacity of these plants is approximately 56 million litres (100 kilolitres per day) and is similar in production capacity to fairly large commercial cellulosic ethanol plants in the USA.

A large number of pilot plant trials on production of second-generation ethanol were taken, mostly in the USA and Europe, during 1990–2005. Much of the basic technology was developed with large state R&D grants. After the basic technology package was developed, the private sector became active and was again supported by liberal state assistance. Some of the major commercial plants for production of cellulosic ethanol from agricultural residues and forest wastes are discussed next.

Mossi Ghisolfi Group (Scott, 2018) of Italy under the separate company Beta Renewables started up operations at the first industrial cellulosic ethanol plant in the world. The plant located in Crescentino, Italy was commissioned at 40 million gallons per year capacity till 2018. Beta Renewables later built a plant in Brazil based on sugar cane bagasse and tops. This company used the enzymes developed by Novozymes and the technology was perfected. However, the parent company underwent some financial problems and the regular operations got interrupted.

The US chemical giant DuPont commissioned a 30 million gallon plant in Nevada, US based upon its own technology and primarily on corn cobs and other agricultural residues. The plant was taken over in 2017, subsequent to reorganization in DuPont, by VERBIO, a German company. In 2015, Abengoa celebrated the opening of a 25 MMgy cellulosic ethanol plant in Hugoton, Kansas, USA. However, in 2016, after experiencing financial difficulties, Abengoa declared its cellulosic bioethanol plant in bankruptcy (Erin, 2016). The other major plants included Raizen that started up operations at its 40 MMgy cellulosic ethanol plant (Iogen Corporation, 2015). In 2014, GranBio started up a cellulosic ethanol plant with a capacity of 20 MMgy in Brazil. However, the plant suspended operations in 2016 due to technical difficulties in the pre-treatment stage and resumed operations in 2019

(Susanne, 2016; Kennedy, 2019). Clariant's sun-liquid technology (Switzerland) is another technology developer offering technologies for multi-feed cellulosic ethanol production. In 2014, POET-DSM Advanced Biofuels, a 50/50 joint venture, commissioned its Project Liberty facility in Iowa, USA. The cellulosic ethanol facility was set up to produce 20 MMgy of ethanol and then ramp up to 25 MMgy (Sapp, 2014).

India has announced setting up of twelve, 100 kilo litre per day capacity plants at different locations and based on rice straw, cotton stalk, and bagasse. Four of these plants are under construction and financed by state-owned national oil companies and are likely to be operational by 2021–22.

TABLE 1: Indicative biofuel yield per tonne of feedstock from biochemical and thermochemical routes

Process	Biofuel yield (litres/dry ton)		Energy content (MJ/L)	Energy yields (GJ/ton)	
	Low	High	Low heat value	Low	High
Biochemical					
Enzymatic hydrolysis ethanol	110	300	21.1	2.3	6.3
Thermochemical					
Syngas to Fischer–Tropsch diesel	75	200	34.4	2.6	6.9
Syngas to ethanol	120	160	21.1	2.5	3.4

Source: IEA/OECD Report 2017

The literature references report a very large range of biofuels adopting different routes. Biochemical route from lignocellulosic materials is reported to give a better yield as compared to one from thermochemical routes. However, these are general indications for a given biomass. Biochemical route is good for materials such as corncob and agricultural residues, but when it comes to harder materials like forestry waste or even cotton stalk, thermochemical methods are more suitable.

Even within the industry, a comparison of these two technology routes has proven to be very contentious. Unavailability of published cost data has been the biggest limiting factor. These limitations notwithstanding, the IEA has estimated the commercial-scale production costs of second-generation biofuels to be in the range of US$0.80–1.00/litre of gasoline equivalent (lge) for ethanol. This range broadly relates to gasoline wholesale prices (measured in US$/lge) when the crude oil price is US$100–130/bbl.

Lignocellulosic conversion technology	Assumptions	Production cost- By 2010 USD /lge	By 2030 USD /lge	By 2050 USD /lge
Bio-chemical ethanol	Optimistic	0.80	0.55	0.55
	Pessimistic	0.90	0.65	0.60
BTL diesel	Optimistic	1.00	0.60	0.55
	Pessimistic	1.20	0.70	0.65

FIGURE 5: IEA second-generation biofuel cost estimates (under alternative scenarios)

IEA report of 2008 had made some predictions on costs of bioethanol and BTL liquids from biomass. As can be seen from Table 2, these estimates of production costs were not met in 2010 and even today biochemical ethanol is about 50–70% more expensive than first-generation conventional ethanol.

Biorefinery Approach -Biofuels and Biochemicals

The global investments on new cellulosic ethanol plants have seen a decline in the last 5 years mainly due to higher cost of production and some technical difficulties. In order to bring down the cost of production of cellulosic ethanol, a biorefinery concept is being advocated that involves production of some high value biochemicals to cross-subsidize the cellulosic ethanol. However, most of the technologies behind these chemicals are under development and their commercial feasibility is uncertain.

Two major barriers exist for the immediate integration of the sugar-to-biochemical technologies into the second-generation bioethanol process. The first is the presence of by-products generated during the pre-treatment stage, which has a detrimental effect on the microorganisms and catalysts used to convert sugars to chemicals. Therefore, separation and purification technologies that remove detrimental compounds must be optimized and introduced into the second-generation bioethanol process to generate a relatively pure sugar stream. However, the development of such technologies requires extensive research and their implementation will increase the capital and operating costs.

In 2004, the US Department of Energy prepared a report listing 12 promising bio-based chemicals from a sugar-based platform. These compounds were considered the potential building blocks for the future (PNNL, NREL, Werpy, *et al*., 2004). In 2012, IEA Bioenergy published a report that highlighted bio-based chemicals with immediate potential for commercialization. Listed products were selected based on their strong market growth, industrial investment, and demonstration programmes (Jong, Higson, Walsh, *et al*. 2012). In 2007, the US Department of Energy published a report evaluating opportunities to convert lignin into power, macromolecules, or aromatics, such as methanol, cyclohexane, styrene, phenol, among others (Holladay, White, Bozell, et al., 2007). Since lignin constitutes up to 30% of the weight and 40% of the fuel value of biomass, lignin represents a valuable opportunity to increase the commercial viability of a biorefinery. First-generation bioethanol is currently used to manufacture various compounds, such as ethyl acetate, ethylene, ethylene glycol, or acetic acid. Since the ethanol stream produced in the second-generation ethanol process has no major impurities, commercialized technologies for the conversion of ethanol to biochemicals can be immediately integrated with second-generation ethanol. Some of major biochemicals that can be produced in biorefinery approach are as follows:

1. The compound 1,2-butanediol (1,2-BDO) or 1,2-butylene glycol can react with a dicarboxylic acid, for example, phthalic acid or adipic acid, for use as a polyester polyol or a plasticizer. It is estimated that the butanediol market is approximately $4 billion per year (2016) with a volume of 1.5 mtpy, which is expected to grow to more than $7.5 billion per year and 2.7 mtpy by 2020 (De Sanctis, 2016). However, actual figures produced in 2020 are slated to be lower due to pandemic (Global Chemical watch).

2. 1,3-Propanediol (1,3-PDO) as a monomer for the polycondensation reaction to produce polyesters, polyethers, and polyurethanes. An approach to generating microbial 1,3-PDO is through the use of two organisms, one that ferments sugars to glycerol and another that ferments glycerol to 1,3-PDO. In a second-generation ethanol process, 1,3-PDO could be produced using a portion of the hydrolysate stream generated.

3. As a bulk chemical, 1,4-butanediol (1,4-BDO) is used in the manufacture of polymers, solvents, and chemicals. 1,4-BDO is a large volume chemical that has a global market approaching 2 million tonne per year. Burgard, Burk, Osterhout, et al. (2016) engineered an E. coli strain that produces 1,4-BDO from dextrose, sucrose, and cellulosic biomass sugars. Although the production of 1,4-BDO via fermentation is environmentally attractive, further optimization and research are required to achieve a commercial production.

4. 2,3-Butanediol (2,3-BDO) or 2,3-butylene glycol is an isomer of butanediol that is used to manufacture printing inks, perfumes, fumigants, moistening and softening agents, explosives, plasticizers, foods, and pharmaceuticals. Results indicate that hydrolysate produced during the second-generation bioethanol process may be suitable to generate 2,3-BDO and several companies have patented bioprocesses.

5. Isobutanol, lactic acid, glutamic acid, xylitol, furfural, and itaconic acid are other valuable products that can be obtained from hydrolysed sugars of biomass in second-generation ethanol production process.

Algal-Based biofuels and products

Algal biomass can undergo a variety of processes to produce both biofuels and fungible fuels as depicted in Figure 6.

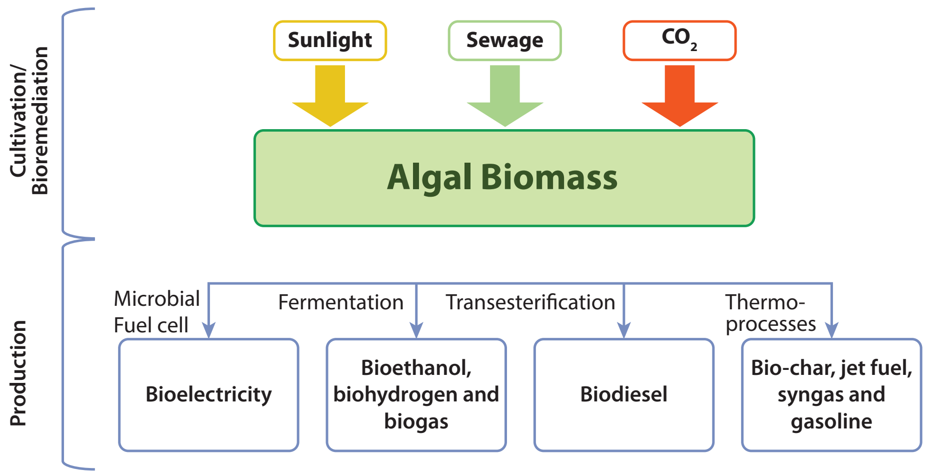

FIGURE 6: Algal biomass

Treatment plants render it unfeasible, costly, and energy intensive to carry low-quality water for long distances. Moreover, water will not be completely recycled (Office of Energy Efficiency and Renewable Energy, 2010). Although algal biodiesel production presents a possible carbon-neutral source of the transportation fuel, the lack of commercial success raises questions regarding the feasibility of the process. Numerous economic and environmental impact assessments have produced highly variable results, predicting costs in the range of Rs 100–3000 per litre. Productivity and provision of nutrients, as well as energy and water usage, are the key challenges to algal biodiesel production. Carbon dioxide supply may represent the single most important challenge to algal biodiesel, while recycling of other nutrients (specifically nitrogen and phosphate) is essential. Finally, a careful balance must be struck between energy and water consumption; this balance is primarily dependent upon bioreactor design. Process economics are enhanced by integrating biodiesel production into a biorefinery, producing high value products.

Freshwater algae, in open pond, for biofuel is mostly ruled out due to loss of water on evaporation and restricted availability. It is estimated that about 123 trillion litres of water will be required to replace only 5% of gasoline/diesel with algal biofuels. The use of wastewater is one such good option as it also provides some of the nitrogen and phosphorous. However, a major drawback is that wastewater may contain algal pathogens and predators, heavy metals, and other contaminants. Also, most algae production sites exist far away from wastewater.

The energy cost of algal extraction is 10-fold higher than the energy cost of soybean oil extraction. The cost was reported in 2012 to be $27 per gallon (Savage, 2012). Some estimates for the cost of production including all capex and operating expenses indicate that algal biodiesel may be five to eight times the cost of petrodiesel taken at crude cost of $60 a barrel.

In any fuel production system, EROI (energy return on investment) is an indicator of the self-economic sustainably of process and processes with value less than 1 are undoubtedly unsustainable. The estimated EROI for algal biofuels produced in open ponds or photobioreactors is 0.13–0.71 (Hall, Dale, and Pimentel, 2011). Algal biofuel production can be scaled up by constructing the facility, chemicals, pumps, cooling, CO_2 pipelines, filters, harvesting, centrifuges, storage, surface structure for open ponds, pH, salinity, extraction and conversion, transport, recycling water and nutrients, and delivering fuels (Sills, Paramita, Franke, *et al.*, 2012; Youngs and Somerville, 2013).

Algae Process in Biorefinery Mode

The DBT-TERI Centre of Excellence (CoE) in Advanced Biofuel and Bio-commodities, supported by Department of Biotechnology, Governemnt of India, is working to generate biofuels through the marine algal route for assessing their sustainability. They in collaboration with IIT Guwahati, Indian Agricultural Research Institute, and Transtech Green Energy are studying algal growth in a 100,000 litre bioreactor. The algal biomass after lipid extraction, in wet phase, will be subjected to pyrolysis to get bio-oil that can be upgraded by deoxygenation and hydroprocessing to diesel and jet fuel. The glycerol obtained from lipid transesterification can be catalytically converted to acrylic acid. The algae biomass shall be converted to biodegradable cellulose nanofiber for the downstream application in the production of biodegradable plastic by IIT Guwahati. Therefore, algal production undergoes value product generation via biorefinery approach. The completion of project, in another couple of years, will bring out the cost benefits of processing algae in a biorefinery mode.

Hydrogen as a Renewable Fuel

Hydrogen technologies have received considerable attention in recent years. Hydrogen has been used in oil refining for hydrogenation purposes and in production of urea and methanol. Almost all of it comes from fossil fuels, emitting today more than 800 $MtCO_2$ (million tonne of carbon dioxide). IEA report on Energy Technology Perspectives 2020 indicates global hydrogen demand in 2019 at 75 MtH_2 (or 215 Mtoe) (IEA, 2020). Most of this hydrogen was produced from natural gas reforming including water shift reaction and thus co-produced huge amounts of CO_2 and nowhere this CO_2 was captured using CCUS technologies, as these are still under development.

Fossil fuels, mostly natural gas, without CCUS, initially continue as the main source of hydrogen production worldwide in the next decade. However, after 2030 almost all the growth in output comes from low-carbon hydrogen, increasingly using renewable-based electricity in regions with good solar and wind resources, or from fossil fuels in combination with CCUS. In 2070, electrolytic hydrogen is estimated to account for nearly 60% of global hydrogen production. The recent report by IEA, Energy Technology Perspectives 2020, covers the estimates of hydrogen production and its use in the transport sector by 2040 and 2070 (IEA, 2020).

Water electrolysis splits water in an electrochemical process into hydrogen and oxygen. Today, water electrolysis globally accounts for less than 0.1% of dedicated hydrogen production. With declining costs for renewable electricity, there is renewed interest in electrolytic hydrogen, which has resulted in an increasing number of projects with significant electrolyser capacities being commissioned or announced. Global installed electrolyser capacity is estimated to increase from around 170 MW in 2019 to more than 3300 GW by 2070 (IEA, 2019). The global capacity of electrolysers, which produce hydrogen from water and electricity, will increase to 300 GW from 0.2 GW today. Global hydrogen demand will increase sevenfold to 520 MT by 2070. Hydrogen by 2070 will be used in the transport sector for cars, trucks, and ships (30%), while 20% of hydrogen will be used for production of synthetic kerosene for the aviation sector.

Hydrogen as a Transportation Fuel – Mission Hydrogen Economy

Currently, most of the hydrogen produced in the country is by reforming of natural gas or petroleum naphtha and both these processes are neither green (CO_2 is evolved during reforming) nor are from renewable sources. Biomass-based hydrogen production has the potential and there is a need to be explored towards making it economically feasible and sustainable. Bio-H_2 can also contribute immensely only if the cost of production is brought down by selecting cheaper feedstocks than used at present, mostly sugar-containing materials. Recently, the Finance Minister in the Union Budget for 2020–21 formally announced the NHM that aims for generation of hydrogen from green power resources.

One of the colossal challenges faced by the industry for using hydrogen commercially is the economic sustainability of extracting green or blue hydrogen. The technologies used in production and use of hydrogen such as carbon capture and storage (CCS) and hydrogen fuel cell technology are at the nascent stage and expensive that in turn increases the cost of production of hydrogen. The commercial usage of hydrogen as a fuel and in industries requires mammoth investment in R&D of such technology and infrastructure for production, storage, transportation, and demand creation for hydrogen.

On policy side, currently multiple regulatory authorities regulate hydrogen use tangentially; for instance, Ministry of Road Transport and Highways regulates vehicle's fuel carrier specifications, MNRE regulates renewable energy sources, Petroleum and Natural Gas Regulatory Board regulates pipelines, and Petroleum and Explosives Safety Organisation regulates explosive substances, storage, and fuel station's specifications. Different storage systems are another key area that requires a lot of R&D. In the development of pressure cylinders, many parts need to be indigenized. Start-ups could be supported to fill such requirements (US Department of Transportation and US Department of Energy, 2009). In March 2020, Department of Science and Technology, Government of India published the status of hydrogen in India. This extensive report covers hydrogen production, hydrogen storage, hydrogen transport and utilization – fuel cell; current issues, and way forward.

Hydrogen can be used as an automotive fuel through both fuel cells and internal combustion engines. Although the fuel cell systems are proven to be more efficient than internal combustion engines, they require more development in terms of infrastructure. Hydrogen has a high energy density as compared to other fuels, and thus it produces more energy in lesser weight due to which it can prove to be a viable option for heavy vehicles covering long routes in the future. The refuelling time required for hydrogen is also lesser when compared to electric vehicles and vehicles running on conventional fuels.

Hydrogen can be transported through compressed gas tanks, pipelines, and cryogenic liquid hydrogen trucks (Ministry of New and Renewable Energy, 2016). The transportation of compressed hydrogen through tube trailers requires high operation and maintenance costs. Liquefying hydrogen is costlier than compressing hydrogen; however, cryogenic liquid trucks can deliver more volume of hydrogen than compressed trailers, thus reducing the costs. Supplying hydrogen through pipelines has been found to be cheaper than the other available modes of delivery. It is essential to exercise caution during the storage, transport, and delivery of hydrogen as it is flammable in nature and has low ignition trigger. Hydrogen is also light in weight that increases the chances of its leakage. The compliance of safety standards and guidelines, thus, is imperative while dealing with hydrogen. The development of hydrogen as an automotive fuel has gained momentum worldwide. Hydrogen-fuelled cars and buses are already in use in the United States, Japan, South Korea, China, and Germany. Japan has announced to run fuel cell buses and cars for the Tokyo 2020 Olympics to promote the use of hydrogen. Now games slated on 23rd July to 8th August 2021 will have Hydrogen Olympic Village. The Olympic Village will be located in the city of Tokyo and will act as a miniature hydrogen society. Hydrogen will be used to provide the electricity for dormitories and power fuel cell buses to ferry the athletes between venues around the city. Toyota will be supplying 100 hydrogen fuel cell buses (FCB) to shuttle athletes and visitors around the Olympic competition.

Indian Initiatives on Hydrogen and H-CNG

Indian government has taken hydrogen economy as a mission programme. First electrolyser-based hydrogen generator was installed at solar research institute of MNRE in Gurgaon. This will fuel buses for field trials. A hydrogen fuel cell bus has been launched in India by Tata Motors in collaboration with the Indian Space Research Organization (ISRO) and Indian Oil (IOCL).

Indian Oil Corporation has initiated a pilot project for using hydrogen-enriched compressed natural gas (H-CNG) in vehicles. The Supreme Court had also recommended introduction of H-CNG in Delhi and directed IOCL to complete this pilot project soon [30]. IOC (R&D) has set up two H-CNG stations in NCR region based upon its own patented production technology. In October 2020, field trails on 50 Delhi buses fuelled with 18% hydrogen containing CNG was started. H-CHG results in drastic reduction of CO and particulates and also provides better fuel economy. H-CNG has been found to be more efficient than CNG in terms of reducing emissions. IOCL has developed a patented single-step procedure for partial reforming of methane to mixture of 18% hydrogen and methane and this resultant blend is expected to lower down emissions and be cost-effective.

NITI Aayog has also recommended the use of H-CNG by utilization of the existing piped gas infrastructure in Delhi. It has further recommended that H-CNG be notified as an automotive fuel, standards for its use be issued by the Bureau of Indian Standards (BIS), and clearance for H-CNG storage cylinders on vehicles be issued by the Petroleum and Explosives Safety Organisation (PESO) (NITI Aayog and Confederation of Indian Industry, 2018).

However, the production of hydrogen and dispensing it through a compatible storage and transport network is a capital-intensive affair. Although research and development for hydrogen in India is underway, importance should also be given towards making hydrogen economically viable in order to compete with the conventional fuels and electric vehicles that have attained more market maturity than hydrogen. Hydrogen is largely produced from fossil fuels, and hence it is essential that producing hydrogen from renewable resources is prioritized by the government.

At present, the use of hydrogen in vehicles in India is limited to research, demonstrations, and test runs. The fuel cell technology is still expensive in India and the government, therefore, must come up with a cost-effective plan to develop the same on a large scale. It will also need to invest heavily towards establishing the required infrastructure consisting of hydrogen delivery network, storage and transport systems, and refuelling stations.

Compressed Biogas

Biomethane can be blended up to any share into natural gas grids by making use of existing gas infrastructure. The global average blending share of biomethane reaches 16% in 2070, 50% in the European Union and 67% in China in 2070. India has started big programme on biogas production, but the grid blending, due to smaller production sites, is yet to begin.

Biogas can be produced from organic waste feedstocks, such as crop residues, animal manure, and organic municipal solid waste or wastewater sludge, by means of anaerobic digestion, which is a mature technology (IEA, 2020). The resulting biogas, a mixture of methane, CO2, and smaller quantities of other gases, is used today for power generation in internal combustion engines with an installed global capacity of around 8 GW. Biogas can also be used as a clean cooking fuel to replace fossil based LPG or traditional biomass use. By removing the CO2 and other contaminants, biogas in addition can be upgraded to biomethane, which can be compressed or transported though pipelines. IEA report indicates production worldwide to be growing from 30 Mtoe at present to 335 Mtoe in 2040 and 390 Mtoe in 2070. Anaerobic digestion remains the route for biomethane production using lignocellulosic and other organic waste materials.

Indian Biogas Scenario

Currently, India imports about 50% of its natural gas requirements. CBG has the calorific value and other properties similar to CNG and hence can be utilized as the green renewable automotive fuel. Thus, it can replace CNG in automotive, industrial, and commercial areas, given the biomass and cattle dung availability within the country. Waste/biomass sources such as agricultural residue, cattle dung, sugar cane press mud, municipal solid waste, and sewage treatment plant waste produce biogas through the process of anaerobic decomposition. The biogas is purified to remove hydrogen sulfide (H_2S), Carbon Dioxide (CO_2), and water vapour and compressed as CBG, which has methane (CH_4) content of more than 90%, typically 95%.

Biogas in India has been around for a long time. In the 1970s, the country began the National Biogas and Manure Management Programme (NBMMP) for household and municipal scale biogas production. The country did a great deal of research and implemented a wide variety of ideas to help its people become more self-sufficient. Regardless of these efforts, diffusion of biogas technologies is constrained by several financial, social, and institutional factors. India's production of biogas is quite small. It only produces about 2.07 billion m3/year of biogas, while it is estimated that it could produce as much as 48 billion m3/year. This means that there are various issues with the current methods India is using in its biogas production. Mittal, Ahlgren, and Shukla (2018) listed various issues as to why past experience of biogas in India was not very good.

Sociocultural barriers like objections towards using animal and human waste as the raw material, technical and informational barriers such as lack of technical capacity for construction and maintenance, and ownership issues were main barriers. Out of 12 million family biogas plants planned by MNRE, around 5 million family biogas plants (40%) have been installed by 2018 and majority are not operational due to the above-mentioned issues.

The estimated CBG potential from various sources in India is nearly 62 MMT with bio-manure generation capacity of 370 MMT. CBG is envisaged to be produced from various biomass/waste sources including agricultural residue, municipal solid waste, sugar cane press mud, distillery spent wash, cattle dung, and sewage treatment plant waste. The other waste streams, namely, rotten food from cold storage, rotten vegetables, dairy plants, chicken/poultry litter, food waste, horticulture waste, forestry residues, and industrial effluent treatment plants (ETPs) treating organic waste can also be used in the generation of biogas.

Biogas is anaerobic degradation of organic matter by bacteria. The biogas generation process consists of four subsequent chemical and biochemical reactions, that is, hydrolysis reaction, acidogenesis reaction, acetogenesis reaction, and methanogenesis reaction. Pressure swing adsorption (PSA) is the most prevalent purification technology for large biogas systems in India. With this technique, carbon dioxide is separated from the biogas by adsorption on a surface under elevated pressure. Hydrogen sulphide and water need to be removed before the PSA-column. There is significant loss of methane (20–30%) in this process.

Water scrubbing is another technique for purification of biogas considering that carbon dioxide has a higher solubility in water than methane. Carbon dioxide will therefore be dissolved to a higher extent than methane, particularly at lower temperatures. In the scrubber column, carbon dioxide is dissolved in the water, while methane concentration in gas phase increases. The gas leaving the scrubber has therefore an increased concentration of methane. There are technologies available through which 97% purity of methane can be achieved with minimal (<5%) methane loss.

Sustainable alternative towards affordable transportation

Realizing great potential for biogas in country, Government of India has taken time-bound initiatives to produce CBG at very large scale. The first CBG plant established under the scheme is at Namakkal (Tamil Nadu). The National Policy on Biofuels 2018 also emphasizes the active promotion of advanced biofuels, including CBG. Earlier, the Government of India had launched the Galvanizing Organic Bio-Agro Resources (GOBAR-DHAN) scheme to convert cattle dung and solid waste in farms to CBG and compost.

The SATAT (Sustainable Alternative Towards Affordable Transportation) initiative was launched in October 2018 by the Ministry of Petroleum and Natural Gas in association with public sector undertaking (PSU) and oil marketing companies (OMCs) and aims to achieve production of 15 MMT of CBG from 5000 plants by 2023. Under this scheme, CBG production plants will produce CBG that will be available in the market for use in automotive fuels through private sector entrepreneurs. CBG produced at these plants will be transported through cascades or through pipelines to the fuel station networks of oil PSUs for marketing as a green transport fuel alternative.

The SATAT scheme has a very strong social linkage as this initiative is expected to generate direct employment for 75,000 people and produce 50 million tons of bio-manure for crops. Thus, it will provide boost to entrepreneurship, rural economy, and employment as well as reduction in import of natural gas. Additionally, this will lead to better waste management and reduction in carbon emission.

Oil PSUs have offered ₹46 per kg basic price for procurement of CBG meeting standard and compressed at 250 bar and delivered at their retail outlets in cascades. This basic price is fixed for a period of 3 years from October 1, 2018. The entrepreneurs would be able to separately market the other by-products from these plants, including bio-manure, carbon dioxide, and so on, to enhance returns on investment. Though the initial response of private players is very encouraging, better price for CBG is being demanded.India relies heavily on crude oil imports, as domestic production is not sufficient to meet the country's soaring refinery activity and end use demand. Over the past decade, India's crude oil net imports have increased by almost 90%, while domestic production has stagnated. India is the world's third largest consumer of oil, the fourth largest oil refiner, and a net exporter of refined products due to its very large refining capacity. India produces significantly more diesel and gasoline than needed for domestic consumption, which contributes to its exports of oil products. India exported significant amounts (55 MMT in 2018) of diesel and gasoline taking advantage of the surplus refining capacity.

Crude oil production has been nearly stagnant and increased only 3% from 2008 to 2018. India in 2018 consumed about 220 MMT/year of oil and about 80% of this is imported. As proven oil reserves are limited compared to domestic needs, India's import dependency (above 80% in 2018) is going to increase significantly in the coming decades. However, India has a surplus refining capacity (270 MMT/year) and exports about 50 MMT/year of refined products. In 2018, India spent a total of US$25 billion on subsidies for the consumption of fossil fuels, according to the latest IEA data (IEA, 2019b), mostly supporting oil consumption in the form of LPG (US$17 billion) and gas consumption (US$4 billion). However, the total value of fossil fuel subsidies is only 1% of GDP. Transport sector consumes about 42% of the total oil (~90 MMT/year), followed by domestic (17%) and industry (12%). The transport sector is also a major contributor to GHG emissions (~24%), and therefore for energy security and environmental reasons, transport sector merits sharp focus. The discussions in this chapter will mostly confine to current status, technologies under development, and future potential of biofuel use in the transport sector.

Biofuel Programme in India

India has a long-standing ethanol blending programme. In 2009, India came up with the first biofuel policy for its biofuel blending mandates in transport fuels, mainly diesel and gasoline. However, the micro planning before setting up of huge targets was missing and the targets were based on some assumptions. For example, the target set in 2009 of 20% ethanol blending by 2017 was missed almost entirely as the blend rate reached only 1.9% that year (NITI Aayog and Confederation of Indian Industry. 2018). Similarly, India failed to meet its 2010 target for 20% biodiesel blending, with a blend rate of less than 0.1% in 2017 [32].

Figure 7 shows the supply of ethanol, its current uses, and deficit for blending programme. These figures are for production of ethanol only from leftover molasses of sugar production and clearly shows that this single feedstock is not sufficient to meet the blending needs.

Year	Supply	Blending*	Industrial	Potable	Total Demand	Deficit	% Deficit
2016-17	2,993	1,532	1,252	1,030	3,815	822	21%
2017-18	3,089	1,664	1,296	1,061	4,021	933	23%
2018-19	3,187	1,803	1,342	1,093	4,238	1,051	25%
2019-20	3,289	1,952	1,389	1,126	4,466	1,177	26%
2020-21	3,395	2,109	1,437	1,159	4,706	1,311	28%
2021-22	3,503	2,283	1,487	1,194	4,964	1,461	29%

*Ethanol demand is projected using the expected growth in petrol demand in the given period
All the quantities above are in million litres. CAGR of ethanol -3.2%

FIGURE 7: Ethanol supply demand for blending

The mandated level of 5% ethanol blending has not been met to date, although 2017/18 saw a record high blending rate of over 4% achieved. Today around 2 billion litres of ethanol are consumed across India and in several union territories where the programme has been implemented by OMCs.

Table 3 clearly indicate that though there has been constant improvement in supply of ethanol for gasoline blending, still there is huge gap on tendered quantity and actual supply. New biofuel policy with extended feedstocks and technologies will surely substantially improve blending rates.

TABLE 2: Ethanol procured by oil marketing companies for gasoline blending (MoPNG data)

Ethanol supply year	Tendered quantity (crore litre)	Quantity allocated (crore litre)	Quantity supplied (crore litre)	Blending percentage (PSUs and OMCs)
2012-13	103.0	32.0	15.4	0.67%
2013-14	115.0	70.4	38.0	1.53%
2014-15	128.0	86.5	67.4	2.33%
2015-16	266.0	130.5	111.4	3.51%
2016-17	280.0	80.7	66.5	2.07%
2017-18	313.0	161.04	150.5	4.22%

Consumption has fallen well short of more ambitious 10% blending targets for ethanol-producing states and of 20% blending goals. In the past, there was no formal national mandate for biodiesel blending, but several more localized 5% blending initiatives have been undertaken. Fuel distribution is largely in the hands of public sector national OMCs. India's biodiesel production is still at an early stage of development, allowing blends of up to 5%. There are some outlets in a few states that offer B5 diesel made from palm sludge or locally available non-edible oilseeds. India's biodiesel production is still at an early stage of development and very little blending has taken place because of the supply side constraints.

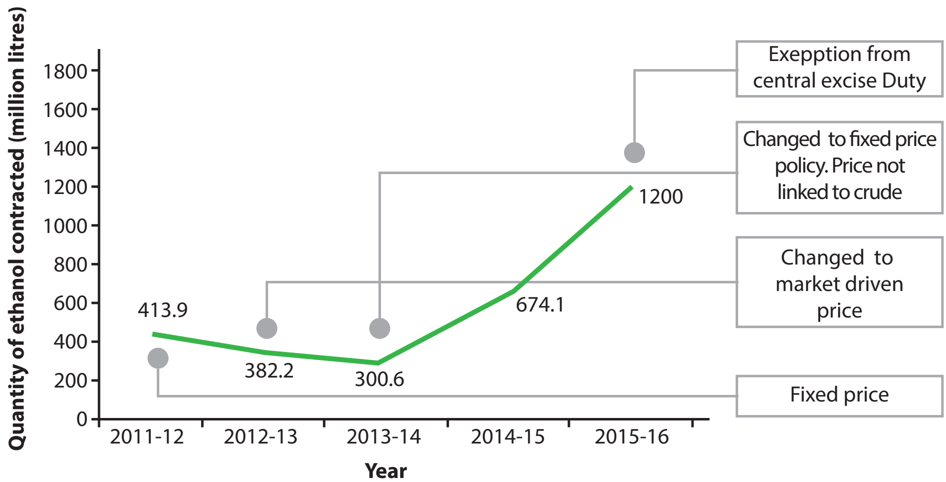

FIGURE 8: Ethanol volumes offered for blending to OMC

Figure 8 shows the amount of ethanol blended in gasoline and the effect of ethanol pricing in early years of blending programme as per the first biofuel policy from 2011 to 2016. Government policies such as excise duty exemption and increased procurement price saw a quantum jump in ethanol availability.

Year	Biodiesel Procured by OMCs for blending (million Litre)
2015-16	11.9
2016-17	35.9
2017-18	43.6
2018-19	82.1

FIGURE 9: Biodiesel blending in petro-diesel by OMC (MoPNG data)

Biodiesel production and use has been even lesser than bioethanol. India's biodiesel programme initially relied on use of non-edible seeds like jatropha and karanjia for which large-scale field trials for plantations were carried out. It was observed that yield of these oilseeds is much lower than expected. Figure 7 shows how little biodiesel was procured and blended in diesel. Applications of technologies such as FT (Fischer–Tropsch process) of biomass gasification and production of synthetic diesel and HVO (hydrotreated vegetable oil) production from UCO (used cooking oil) in refineries increase biodiesel blending pool.

In India, there are currently no gasification plants for the production of advanced biofuels, although there is a significant degree of work in gasification for power and heat generation. India has severe shortage of vegetable oils. There is no dedicated HVO plant in India. However, Indian Oil Corporation had developed technology based on Jatropha oil and this technology of co-processing was tested at 1000 tons scale in a IOC refinery. In this technology, it is not necessary to set up a new green field processing unit, but only minor modifications are required in the existing petroleum processing plant. India's National Biofuel Policy 2018

Based upon the experience of the first biofuel policy, in 2018 the Government of India through Ministry of Petroleum and Natural Gas (MoPNG, 2018) introduced a new biofuel policy covering both conventional and advanced biofuels. This superseded the previous biofuel policy of 2008. The new policy proposes an indicative target of 20% ethanol blending in gasoline and 5% biodiesel blending in diesel by 2030.

The new national biofuel policy widens the range of feedstocks allowed to be used as a base for ethanol – expanding from only the molasses produced by India's large sugar industry to include sugar cane juice, sugar, and starch crops (e.g., corn and cassava) in years when there is a projected oversupply and damaged foodgrains. This is anticipated to support production growth. The new policy links ethanol and sugar cane pricing and establishes differential prices for ethanol depending on production feedstock. These feedstocks are still primarily non-food feedstocks; however, some grains unfit for human consumption that do not threaten food security and some part of sugar cane juice have been included.

Specifically, India plans to meet its ethanol mandate of ethanol blending to 20% by 2030; the policy also includes a much realistic target for biodiesel mandate at 5%. The new policy links ethanol and sugar cane pricing and establishes differential prices for ethanol depending on production feedstock. The new biofuel policy outlines several measures to support advanced biofuel production, including additional tax incentives and a higher purchase price than that for conventional biofuels.

The new biofuel policy also aims at promoting second-generation cellulosic ethanol for which 12 commercial plants, each of 100 kilo litre ethanol/day, are planned. To support cellulosic ethanol plants, a Viability Gap Funding (VGF) scheme has been operationalized and pilot scale demonstration of new technologies is also supported. The main attraction of the new policy is assured market of biofuels at reasonable price by major national oil companies. Technologies such as gasification combined with Fischer–Tropsch synthesis and biogas from anaerobic digestion are also being supported under specific schemes.

India has enormous potential to produce biofuels from crop residues (lignocellulosic materials). Residue use varies by region and depends on the calorific values, lignin content, density, palatability by livestock, and nutritive value. While a lot of cereals and pulses have fodder value, the woody nature of others (rice husk/straw, maize stalks and cobs, and ligneous residues) makes them a natural choice to be used as feedstock in the production of biofuels. The estimated total amount of residues used as fodder was 301 MT in 1996–97 (CMIE, 1997) and 360 MT in 2010–11 (Purohit and Fischer, 2014). This accounts for approximately 53% of total residue (Purohit and Fischer, 2014).

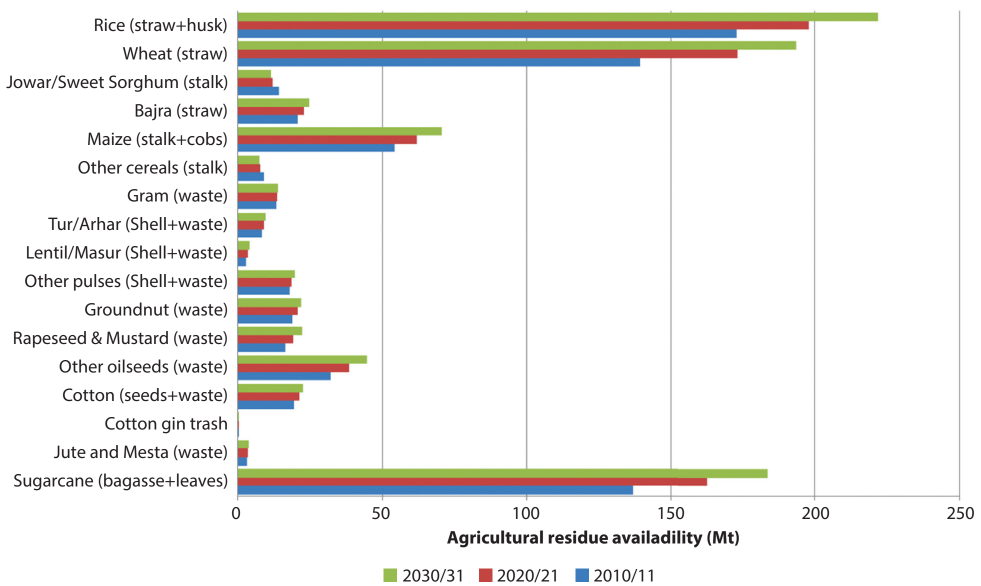

FIGURE 10: Gross residue available from crop production in India

Source: Purohit and Dhar (2015)

The use of biomass as feedstock in biofuels is predicted to double in 2070 from today's levels to 14% (IEA report 2018). In biofuel production, the feedstock cost is the major input cost and can be about 30–50% of the delivered biofuel costs. Additionally, there is need for sustained availability of feedstock throughout the year at reasonable price. Indian bioethanol programme, which was completely on sugar cane molasses, suffered first on account of supply side constraints and then on account of cyclical nature of sugar cane production. In the case of cellulosic ethanol from agricultural residue, collection, densification, transportation, and storage become extremely important. A typical 100 kL ethanol per day plant, like the ones planned by oil PSUs, based on rice straw would need 500–700 tonne per day. As the window of collection of the straw from fields is only 2–3 weeks, this material has to be collected, baled, and stored for year-long supply to the plant. This calls for an innovation supply chain management on the scale never seen before.

Biofuel plants need to be set up near to biomass supply regions as the transportation of low bulk density biomass is expensive. Keeping this in view, the first 12 cellulosic ethanol plants by Indian national oil companies are located near biomass-rich regions. These second-generation ethanol biorefineries being constructed by Indian Oil Corporation Ltd (IOCL), Hindustan Petroleum Corporation Ltd (HPCL), Bharat Petroleum Corporation Ltd (BPCL), Numaligarh Refinery Ltd (NRL), and Mangalore Refinery and Petrochemicals Ltd (MRPL) are planned in 11 states across the country. Their locations are as follows: IOCL – Panipat (Haryana), Gorakhpur (UP), Dahej[24] (Gujarat); HPCL – Bhatinda (Punjab), Badaun (UP), Supaul/Saharsa[1] (Bihar), W. Godavari[1] (AP); BPCL – Bargarh (Odisha), Bina (MP), Bhandara[1] (Maharashtra); NRL – Numaligarh (Assam); MRPL – Davangere (Karnataka).

In 2017, Engineers India Ltd (EIL) prepared a feasibility report on lignocellulosic biomass to second-geenration ethanol for MRPL. A 60 KLPD (60,000 litre per day) plant would cost Rs 690–1100 crore to build with about 20–35% imported equipment. EIL in this report actually compares the technology parameters Capex, Opex, chemical and enzyme consumption, rate of return, and expected cost of ethanol production. These values are compared for technology package provided by the following:

» Praj Industries Limited
» M/s Beta Renewables S.p.A
» M/s Renmatix, Inc.
» DBT – ICT Centre, Mumbai

[24] Tentative location

The detailed comparison of these technologies is beyond the scope of this paper and readers, if interested, can refer to the report Feasibility Report on Ligno-cellulosic Biomass to 2G Ethanol, Mangalore Refinery & Petrochemicals Ltd, Document No. B033-000-03-41-RP-01, June 2017, EIL, which is available online.

Government of India Support for 2G Cellulosic Ethanol

To support cellulosic ethanol plants, a VGF scheme is operationalized and pilot scale demonstration of new technologies is also supported. The scheme called 'JI-VAN Yojana' will be supported with the total financial outlay of ₹1969.50 crore for the period from 2018–19 to 2023–24. Out of scheme fund of ₹1969.50 crore, ₹1800 crore has been allocated for supporting 12 commercial projects and ₹150 crore has been allocated for supporting 10 demonstration projects. Centre for High Technology (CHT) will administer this proposal (February 28, 2019 by PIB Delhi).

Under this Yojana, 12 commercial scale and 10 demonstration scale second-generation ethanol projects will be provided VGF support in two phases:

a) Phase I (from 2018–19 to 2022–23): In this, six commercial projects and five demonstration projects will be supported.

b) Phase II (from 2020–21 to 2023–24): In this, the remaining six commercial projects and five demonstration projects will be supported.

It is understood that four commercial plants being established by PSU companies have been selected for ₹150 crore funding and one pilot project for ₹15 crore funding support.

Synthetic Fuels and other Feedstocks

Synthetic hydrocarbons (diesel, kerosene, aviation fuel, and methanol) are produced by converting hydrogen and a carbon source into long chain hydrocarbons, which are then upgraded to usable fuels. There are several technological routes that can be used to produce synthetic hydrocarbons, including the Fischer–Tropsch process, which uses carbon monoxide (CO) as the carbon source. To be carbon neutral, this CO has to be generated from biogenic CO_2 from a bioenergy source. The production of these fuels requires significant amounts of electricity. Overall, the production of 1 litre of synthetic kerosene from electrolytic hydrogen together with CO_2 captured through DAC requires around 25 kWh of energy. These are still not economic to produce.

Municipal Solid Waste

The diversion of MSW to biofuel production could be particularly impactful in India, as lately the country has developed, in some areas, MSW collection/segregation networks. The majority of MSW is at present disposed either in the open or in minimally managed landfills without on-site methane capture and recovery systems and methane emissions add to GHG load (Kashyap, Chugh, and Nandakumar, 2016). For a landfill without methane recovery, each tonne of landfill waste is estimated to generate approximately 1.3 tonne of CO_2 equivalent emissions as fugitive methane (U.S. Environmental Protection Agency).

In India, the volume of waste generation has been increasing rapidly over the last few years. According to the 'Swachhata Sandesh Newsletter' by the MoHUA (Ministry of Housing and Urban Affairs), in 2019 ~54 MT/year of solid waste was generated from 84,475 urban wards in India. The 2014 report by the 'Task Force on Waste to Energy' under the Planning Commission estimates that urban India will generate 101 MT/year of waste by 2021, 164 MT/year by 2031, and 436 MT/year by 2050.

The organic part of this MSW can be converted mainly to biogas by anaerobic digestion (Ministry of New and Renewable Energy, 2016). India's MSW generation will increase substantially. The MNRE also estimated that total MSW generation will reach 165 MT by 2031, relatively consistent with a World Bank projection of 137 MT in 2025 (Ministry of New and Renewable Energy, 2016; Hoornweg, and Bhada-Tata, 2012).

Properly collected and segregated MSW can be converted to CBG or can be gasified for liquid biofuel generation and this presents an opportunity for very low priced and sustainable feedstock. Even as a few technologies are already operational elsewhere, a lot of technical modifications are required as the composition of Indian MSW is very different to that of the Western countries. Power generation from gasified MSW is under implementation at several places (37).

Dedicated Energy Crops

India does have marginal lands that are not irrigated and cannot support normal agriculture food crops, and some of these can be utilized for growing energy crops for biofuel generation (Pavlenko and Searle, 2018). In the early 1990s, deployment of jatropha, an oilseed crop capable of being grown on degraded lands unsuitable for conventional agriculture, was promoted on large scale (Singh, Singh, Verma, et al., 2014). The then Planning Commission took a lead and based upon limited field trails estimates of jatropha crops were made and a 20% blending mandate for jatropha- derived biodiesel was announced.

However, jatropha failed to live up to its perceived potential because of its low yields, requirement of care, and life-saving water when cultivated on marginal land (Axelsson, Franzén, Ostwald, *et al*., 2011). Cellulosic energy crops such as switchgrass and *Arundo donax* for which there is better knowledge about cultivation can be promoted on marginal lands for biofuel feedstock and to support soil carbon augmentation (Searle, Petrenko, Baz, *et al*., 2016).

In India, the concerns regarding the feedstock availability, economic viability, and sustainability of molasses-based ethanol have necessitated the search for alternative feedstocks to produce ethanol. For example, sweet sorghum has been found to be one such potential source of raw materials for commercial ethanol production due to various advantages. Although sweet sorghum is a suitable feedstock to produce bioethanol, like sugar cane this crop is also grown on water fed fields (though water requirement is lower than sugar cane), and so its large-scale commercialization will hit sustainability criteria.

Used Cooking Oils

Biodiesel is generally produced from triglycerides and vegetable oils, edible or non-edible, by a simple process of transesterification. While the USA could use soybean oil and some EU countries use sunflower oil for biodiesel production, India cannot use any of the edible oils as it is the largest user and also importer of edible oils. In the last two decades, both used cooking oil (UCO) and inedible animal fats have been converted into biodiesel, and to also bio-aviation fuel, through a variety of processes that are at commercial scales. There had been some issues of gum formation on blending of FAME biodiesel in diesel and some auto manufactures have put a limit of about 10% maximum on blending. However, vegetable oils and fat can be processed in oil refineries by adopting a modified hydro-processing process and the diesel so obtained is called green diesel and also a drop-in fuel. Generally, as long as these waste products are not diverted from existing food uses, they can be utilized by the biofuel industry leading to GHG reduction (Ministry of New and Renewable Energy, 2016). India is the largest user of vegetable oils and therefore we do generate vast quantities of UCO, but our replacement and disposal of UCO are unregulated posing a very great health risk to consumers (FSSAI, 2018).

The Food Safety and Standards Authority (FSSAI) of India in 2018 introduced a new requirement that large non-households should monitor their oil quality and also set up a programme to facilitate the collection and fuel conversion of UCO (FSSAI). Of the 23 MT of cooking oil consumed annually in India, FFSAI estimates that 30% (i.e., 6.9 MT) is improperly disposed of and thus available. Of that total, the agency projects that 2.79 MT would be available for biofuel production. There is also a very large disposal of UCO by households who are unaware of adverse health effects of repeated use of cooking oil and also there is lack of collection facilities. Moreover, due to largely unorganized and distributed animal slaughterhouses, collection of animal fat is not carried out.

As of 2018, India's biodiesel industry utilized a combination of inedible vegetable oils, UCO, and animal fats to generate 83 million litres of biodiesel. FFSAI's estimated collection rates indicate that roughly 2.9–3.4 MT of UCO would be available in 2030 (FSSAI). Additional use of animal fat along with UCO presents a hopeful scenario for production of biodiesel and aviation biojet fuel.

Conclusions

India's first biofuel policy of 2009 did not make much impact on introduction of biofuels in market and a new biofuel policy was framed in 2018 learning from experiences. Based on the available analysis, India may find it extremely difficult to achieve the 2030 blend level targets using only sustainable feedstocks and would fall far short of its 20% target for ethanol. However, recently sugar cane juice to ethanol conversion has been encouraged and the government announced on 29th October to increase in ethanol price from this route. This can enable meeting targets provided the country has surplus sugar all these years.

Commercial-scale advanced biorefineries using most abundant feedstocks including crop residues, MSW, and energy crops would become a reality in the next decade. In the near term, India's prospects for biofuel production are mostly limited by feedstock availability and technical constraints. If used cooking oil collection rates are improved, this feedstock could provide enough biodiesel to meet our mandate.

The Government of India has taken several steps to facilitate cellulosic ethanol and CBG. Viability gap funding and assured market have been proposed for 12 large cellulosic ethanol plants. In the next 5 years, a very large number of CBG plants utilizing agricultural waste and animal dung are likely to be on stream. India has an ambitious programme on hydrogen economy for transportation. Hydrogen by water electrolysis from abundant solar power and from biomass gasification can bring about substantial reduction in GHG emissions and also replace fossil-based transport fuels. The next 5 years are going to be exciting to see quantum jump in Indian biofuel programme.

Biofuels is the bioenergy subsector will be hit the hardest by the COVID-19 pandemic. Reduced fuel demand from decreased travel coupled with falling oil prices has led to reduced liquid biofuel production and some plant closures (World Bioenergy Association, 2020). Technologies in early scale of deployment will be hit hard as new investments are avoided by companies struggling with lower revenue. Public sector funding will also reduce to some extent as the health sector will take preference for investments, at least for a couple of years. However, after stabilization, hopefully by 2022, investments in bioenergy sector are likely to resume or even increase from pre-pandemic year 2019.

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CHAPTER 5

Role of Oil and Natural Gas in India's Energy Quest: A 2040 Outlook

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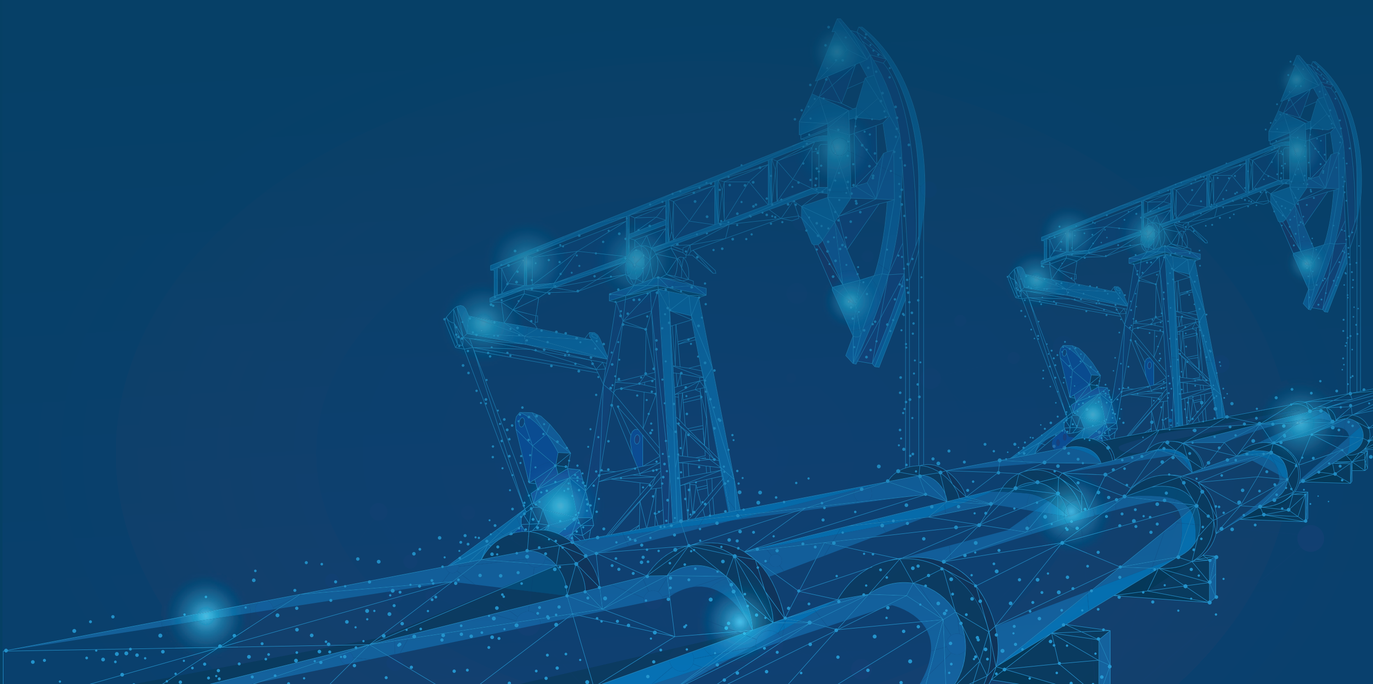

The IEA Review 2021

The International Energy Agency (IEA) in its first in-depth review of India Energy Outlook, 2021, indicated the progress of India's energy strategies, and recommended certain measures to support the government objectives for a better performing energy market, which includes renewable. The Executive Director of IEA, Dr Fatih Birol presented the key findings of the IEA Review in New Delhi in the presence of Minister of Petroleum and Natural Gas, Dharmendra Pradhan, Minister of Coal, Pralhad Joshi, Minister for Power and New and Renewable Energy, R. K. Singh, Vice Chairman of NITI Aayog, Rajiv Kumar, CEO of NITI Aayog, Amitabh Kant and energy secretaries, high commissioners, and the think tanks of India. This is in congruence to IEA's regular conduct of in-depth review of energy policies of its member states and association countries. Crucially, it is the first ever review conducted for India, which has been an IEA-association country since March 2017. According to NITI Aayog Special Secretary, R. P. Gupta, 'As India builds on the remarkable growth and development of its energy sector, this in-depth review will help the Government in meeting its energy objectives by setting out a range of recommendations in each energy policy area (NITI Aayog 2020).' As India is largely becoming prominent in the global energy market, the country's requirement for energy is destined to double by 2040, compared to 25% rise at the global demand, its electricity requirement will triple, and oil consumption will grow faster than other major economies in the world. Therefore, further improving energy security is a key priority for Indian economy, says the IEA (NITI Aayog 2020, NITI Aayog and The Institute of Energy Economics, Japan 2017, BP 2016).

Quest for Oil and Natural Gas Since the 1990s

India today is one of the fastest growing economies in the world. Since 1991, and specifically during the period between 2005 and 2015, the country's Gross Domestic Product (GDP) had increased at a compound annual growth rate (CAGR) of about 7%. During 2005–2015, India's primary energy consumption increased at a CAGR of 6.7%, from 394 million tonnes of oil equivalent (MTOE) to 700 MTOE. From the supply side, oil and natural gas are the major sources of primary energy in India, accounting for approximately 45% share in the country's primary energy basket (Planning Commission 2006a). India has just 0.3% of the world's proven oil reserves, while accounting for 4.5% of the global oil consumption, thus importing about 80% of its oil requirement. Likewise, the country has 0.8% of the world's proven natural gas reserves, but accounts for 1.5% of the world-wide gas consumption, and, thus, importing nearly 40% of its natural gas requirements every year.[25] Every year, the country consumes about 240 million tonnes of oil while its own production is six times less, and produces less than half of the required 58 billion m^3 of natural gas, thus, importing the difference. The International Energy Agency (IEA) projects that India's crude requirement will increase to 7.2 mb/d by 2040 and, thus, it will import a total of around 2.3 mb/d in oil products by 2040, and by that time, its market will constitute more than a quarter of the growth of the global energy demand (Embassy of India 2019). India imported 213.9 million tonnes (MT) of crude 2017 fiscal, about 78% of its demand (Mahajan 2018). If the global fossil fuel supply increases by only 1.7%, as projected by IEA, then India's share in 2030 would range from 5.8% to 8.0% for oil, 2.4% to 4.5% for natural gas, and 16.7% to 26.5% for coal (Planning Commission 2006a). The demand for crude oil in India increased from 203 MT in 2015–16 to 214 MT in 2016–17, registering a growth rate of 5.5% compared to the global average growth of 1.6% (DNA 2017). According to BP Statistical Review of World Energy, June 2016, with its consumption of 4.1 million barrels per day, India has surpassed Japan to become the world's third-largest oil consumer after the United States (19.39 million bpd) and China (11.96 million bpd) (Planning Commission 2006a). By the mid-2020s, according to *BP Energy Outlook*, India will overtake China in terms of its energy consumption (Embassy of India 2019). The country's domestic consumption and fast-growing economy prompts IEA statistics, 'By 2050, the country is likely to be the world's single largest importer of oil' (Sikri 2009, Sahay and Arya 2016). The India Energy Outlook, 2015, published by the IEA, looked at India's role in reshaping the global energy market, because it was set to contribute around a quarter of the total energy demand. Taking into account the fast growing requirements for more hydrocarbons, the energy security possess as one of the top priorities of the Indian government. In the recently concluded International Energy Forum-16 (IEF-16), 2018, New Delhi, Prime Minister Narendra Modi revealed that India's overall energy consumption will grow 4.5% every year for the next 25 years.[26] Today, oil and natural gas resources constitute the largest imported commodity, accounting about 37.5% of India's total imported goods (Sahay and Arya 2016). Further, India's requirement of fossil fuels for the year 2031–2032, based on the scenarios, is projected to be 337 to 462 MT of oil and 99 to 184 MTOE of natural gas (Planning Commission 2006a).

Today, natural gas is slated to play a more important role in the global as well as in India's energy mix, most specifically being a clean fuel, and the global natural gas reserves are inadequately unexploited. India's Hydrocarbon Vision 2025, issued by MPNG, calls for natural gas to be India's preferred energy resource since it is more efficient and cleaner than coal and oil.[27] In 2016, the IEA estimated that India's gas demand is set to grow

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[25] Details available at Ministry of Petroleum and Natural Gas, Government of India, https://mopng.gov.in/en

[26] 'Details available at https://www.narendramodi.in/pm-modi-inaugurates-the-16th-international-energy-forum-in-new-delhi-539611

[27] Details available at http:// petroleum.nic.in/vision.doc

almost 6% annually between 2015 and 2021, and that overall the gas demand will reach to the level of the United States by 2040.[28] However, it is not convinced how natural gas will substitute either coal or oil by 2035 in the total energy mix (Sen 2015). Till date, India has been largely dependent on coal for electricity generation, compared to gas, which is very limited in its availability. India significantly relies on coal consumption that almost doubled over the past 10 years to 407.2 MTOE in 2015. However, in addition to coal and oil, the need for India's natural gas requirements has been limited due to lack of availability. The prospect of demand for natural gas seems very high in India. Like IEA, the BP Statistical Review of World Energy finds huge demand for gas resources in the country. The gas demand in the country will grow by as much as 155% by 2035.[29] Today, India is the fourth largest LNG importer in the world, and the discovery of natural gas hydrates in the Bay of Bengal and in the Indian Ocean in July 2016 could be the game changer for India's energy needs. The findings made by ONGC, the US Geological Survey, and team of scientists from Japan in the Indian Ocean and Indian territory are the first of its kind in the region to explore gas resources; and, if producible, the potential resources in the region will significantly alter India's quest for natural gas. However, because of India's lack of infrastructural facilities to import gas through pipelines and low domestic production, the country's demand for natural gas will remain weaker at least in the medium term, and the gap between the supply and the demand for natural gas in India is likely to increase since economic growth continues to rise rapidly in the country (Grigas 2017). There are also some pressing issues and new trends which are compeling India to look for more and more quantum of gas for clean and efficient use of energy, minimization of pollution, replacement of wood fuels with gas connectivity to households, and the city gas distribution. All these demands and requirements are prompting India to look for more natural gas resources in the international energy market.

Oil and Natural Gas: the keys to energy drive

The energy sector of India is all set for a significant change with the ambitious and ongoing developmental pursuits. By 2022, the government has set a target of 175 GW installed capacity of renewables, 24×7 power for all, housing for all, 100 smart cities mission, and 10% reduction in oil and gas import dependence from the 2014–15 level, and clean cooking fuels. India is set to play a pivotal role in the international energy market. It is envisaged for a 25% rise in global energy demand by 2040, as pointed out by International Energy Agency. As country's energy and electricity requirement is expected to rise at a CAGR of

28 Medium-Term Market Report 2016,Energy Information Administration, p. 11 [AQ: Please provide complete details.

29 Details available at http://www.bp.com/en/global/corporate/energy-economics/energy-outlook-2035/country-and-regional-insights/2015/04/NG-96.pdf.

3.7%–4.5% and 5.4%–5.7% respectively, till 2047, the demand on natural resources to meet the requirement is destined to grow in the future. Having a share of 18% of the global population, the country consumes just 6% of the global primary energy consumption. This is apparent from the low per capita energy consumption of India (521 kgoe in 2014), which is about one-third of the global average. Congruently, India houses about 304 million people who do not have electricity access. This number constitutes 25% of the world's population having no access to electricity, and 800 million Indian people lack access to clean cooking fuels, which makes 30% of the world's population not having access to clean cooking fuels. Therefore, India is definitely destined to reduce its energy poverty in a sustainable manner while gaining energy independence and economic growth. The energy mix of India and the prominent role of oil and natural gas are mentioned in Table 1. According to BP Statistics (2016), in India by 2015, coal constituted 58.1%, followed by oil at 27.9%, natural gas at 6.5%, hydro-electricity at 4.0%, renewable at 2.2% and nuclear at 1.2%. For the world by 2015, oil constituted 32.9%, followed by coal at 29.2%, natural gas at 23.8%, hydro at 6.8%, nuclear at 4.4%, and renewable at 2.8%. This statistics implies that India primarily uses coal (a more polluting source of energy) followed by oil, whereas major patterns of global consumption is comparatively less polluting, that is oil and is followed by natural gas. India has yet to reach at a level of global consumption of less polluting oil and natural gas. Still, coal is expected to remain India's mainstay of future energy, i.e., 42–50% in 2047. India, having the fourth largest coal reserves in the world, would like to use its abundant coal reserves, which is cost-effective and affordable for the end users.

However, climate change concerns and air quality deterioration of Indian cities have prompted for a serious look on the use of hydrocarbon resources. Significant to note, according to WHO, India is home to 22 of the 50 most polluted cities in the world, and according to IEA, air pollution between 2000 and 2018 constituted 300 million tonnes of CO_2 emissions in India (NITI Aayog 2020). Complying with Paris Deal, 2016, India is striving to achieve developmental ambitions with a low carbon footprint. Renewable is clean and green but the problem is that it has not reached the stage of cost-effectiveness and infrastructure availability. Taking stock of these situations, present requirements and future goals, it is imperative for India to reduce the consumption of coal through other means such as oil and natural gas, which are affordable and largely available in the international energy market. In the energy mix, India wants to move towards a gas-based economy, which is more efficient and less polluting, and thus increase its share from the existing 6.5% to 15% by 2022. Likewise, India's LNG imports is set to rise as India has signed long-term deals of 22 MT by 2022 and destined to increase its regasification capacity to 47.5 MT by 2022. India's primary focus on natural gas instead of oil implies that the country is looking for a more efficient fuel and cheaper calorific value.

If taken into account the 2015 data of BP Statistics 2016, India's oil and natural gas consumption together is the second highest in quantum (34.4%) after coal (58.1%), whereas hydro-electric, renewable, and nuclear together constituted just 7.4% of the total mix. Like the 2022 set goals, the 2047 projection by the Indian government envisages pre-eminent role of oil and natural gas by the end of 2047. In BAU scenario and Ambitious scenario, NITI Aayog of India has recommended reducing the country's dependency on coal and oil, while increase the share of renewable and other sources. However, if Table 1 is analysed, then we find that both oil and natural gas in the BAU scenario and Ambitious scenario constituted 10,765 TWh (36%) and 7,787 TWh (33%) respectively, the second highest after coal which is 15,155 TWh (BAU) or 50% and 9,790 TWh (Ambitious scenario) or 42% of energy mix. The nuclear renewable and other non-hydrocarbon resources are yet to take leading roles in reducing oil and natural gas dependencies. Even if all the renewable, nuclear, and other sources of non-hydrocarbon are taken together, the total quantum of demand is less to oil and natural gas taken together in the BAU and Ambitious scenarios by 2047, which constituted 4,238 TWh (14%) and 5, 716 TWh (24%), respectively. Therefore, oil and natural gas will dominate the energy scenario in 2047, second after coal. Although the future plan is to decrease oil dependency yet India has to depend more on oil due to growing domestic requirements. All these can be well illustrated through Table 1.

TABLE 1: Oil and natural gas requirement by 1940s

	2012 (TWh and %)		2015 (%)	2047			
			BAU Scenario (TWh and %)		Ambitious Scenario (TWh and %)		
Nuclear	76 (1)	19	1.2	523 (2)	4,238 (14)	902 (4)	5,716 (24)
Renewable Energy	190 (3)		2.2	2,205 (7)		2,878 (12)	
Agriculture/ waste	1060 (15)		Not available	1,510 (5)		1,936 (8)	
Hydro electricity	NA	NA	4.0	NA	NA	NA	NA
Coal	3,272 (46)	46	58.1	15,155 (50)	15, 155 (50)	9,790	9,790 (42)
Oil	1,938 (27)	2,509 (35)	27.9	8,434 (28)	10, 765 (36)	5,385 (23)	7, 787 (33)
Natural gas	571 (8)		6.5	2,331 (8)		2,402 (10)	
Total	7,108 (100)		99.9	30,158 (100)		23,294 (99)	

Source: NITI Aayog and TheInstitute of Energy Economics (2017)

The various BAU Scenario and Ambitious Scenario imply the need for an aggressive effort in increasing domestic fossil fuel production to meet the domestic requirements. Although the use of hydrocarbon resources is set to decrease owing to climate change obligations yet dependency on quantum of import and consumption will increase and India's dependency for the resources will rise at a mammoth scale. The 2047 BAU Scenario implies the growing demand for coal, oil, and natural gas resources, and even if the Ambitious scenario is taken into account, the demand for oil is destined to rise from the 2012 level (Table 2) and, thus, India has to depend a lot on overseas oil and natural gas resources apart from developing its own resources.

TABLE 2: The import dependence (%)

Sources	2012	2047	
		BAU Scenario	Ambitious Scenario
Coal	17	65	34
Oil	77	90	78
Natural Gas	22	51	33

Source: NITI Aayog and TheInstitute of Energy Economics (2017)

Trade and Investment in Overseas Assets

India has investment in 28 countries in the oil and natural gas assets or projects (Table 3). In most of the cases it has operational rights, while in others it is eligible for joint operations. Russia, Myanmar, Brazil, Colombia and Azerbaijan are the other countries where India has largest investments. Recently India invested in Namibia, and huge discoveries in Mozambique poses bright prospect for future investment in the country. To enhance India's equity investment abroad, some of the significant Indian foreign policy approaches and diplomatic strategies include: the government of India extensively engaging with the oil and natural gas-rich countries through institutional mechanisms such as Joint Commissions, Hydrocarbon Conference, Joint Working Groups and Energy Dialogue for hydrocarbon value chain of the Indian companies. Second, encouraging Indian oil and natural gas companies to pursue acquisition of hydrocarbon assets abroad and energy import, with the objective of increasing the oil and natural gas supply for the requirement of the nation. Third, the MPNG regularly represents India in the global energy dialogues and forums such as the International Energy Forum (IEF), International Energy Agency (IEA), and the Organisation of Petroleum Exporting Countries (OPEC). Fourth, in order to promote bilateral and multilateral engagements with other countries and international organizations on hydrocarbon resources including shale and gas hydrates, the MPNG has entered into numerous collaborative arrangements, agreements, declarations and Memorandum of Understandings (MoUs). Fifth, India is seeking collaboration of the international organizations so as to avail and share technical assistance in Research & Development (R&D), data, statistical model building, and energy forecasts. Sixth, the country has been arranging sector-specific high-level conferences, such as the India-Africa Hydrocarbons Conference, Petrotech, 5th IEF-IGU Ministerial Gas Forum (2016), and International Energy Forum-16 (IEF-16, 2018), to seek investments abroad and get engagement with the oil-rich countries and multinational companies. Seventh, to streamline the production of oil and natural gas abroad, the MPNG has been working in close coordination and cooperation with the Inter-Ministerial Energy Coordination Committee (ECC), Ministry of Finance, National Security Advisor, Prime Minister of India, Ministry of External Affairs, Indian High Commissions or Embassies abroad, and such other senior officials, for addressing the precise issues faced by the Indian oil and natural gas companies (Ministry of Petroleum & Natural Gas 2017).

TABLE 3: India's overseas projects and investments by the end of 2018

S. No.	Country	Name of the Project	Participating Companies and their Shares (%)
1	Australia	Block EP – 413 (onland)	BPRL- 27.803
2	Azerbaijan	ACG, Azerbaijan	ONGC Videsh-2.7213, BP-36 (Operator), SOCAR-12, Chevron-11, INPEX-11, Exxon-8, StatOil-8, TPAO-7, ITOCHU-4
		BTC Pipeline (1760 Km), Azerbaijan	ONGC Videsh-2.36, BP-30.1 (Operator), SOCAR-25, Stat Oil-8.71, TPAO-6.53, ITOCHU-3.4, Chevron-8.9, INPEX-2.5, ENI-5, TOTAL-5, Conoco Philips-2.5
3	Canada	Pacific Northwest LNG Project	Progress Energy Canada Ltd. – 62, Sinopec – 15, Indian Oil – 10, Japex – 10, Petroleum Brunei – 3
4	East Timor	Block JPDA 06-103	BPRL- 20
5	New Zealand	Block- 14TAR-R1,	ONGC Videsh - 100

Contd...

TABLE 3 (Contd.):

S. No.	Country	Name of the Project	Participating Companies and their Shares (%)
6	Sudan	GNPOC, Block 1, 2 & 4, Sudan	ONGC Videsh – 25, CNPC – 40, Petronas – 30, Sudapet – 5 (Jointly Operated)
		Khartoum-Port Sudan Pipeline (741 Km), Sudan	ONGC Videsh-90 (Operator), OIL-10
7	South Sudan	GNPOC, Block 1, 2 & 4, South Sudan	ONGC Videsh – 25, CNPC – 40, Petronas – 30, Nilepet – 5 (Jointly Operated)
		SPOC/Block 5A, South Sudan	ONGC Videsh– 24.125, Petronas–67.875, Nilepet – 8(Jointly Operated)
8	Mozambique	Rovuma Area-1	ONGC Videsh – 16, Anadarko - 26.5 (Operator), OIL – 4; ENH – 15, Mitsui – 20, BPRL – 10, PTTEP - 8.5
9	Libya	Block 43	ONGC Videsh- 100
		Area 95-96	Sonatrach – 50, Indian Oil – 25, OIL – 25
10	Nigeria	OPL- 205	Summit Oil -30
		OML – 142	Suntera Nigeria 205 Ltd – 70, Suntera-50, Indian Oil- 25
11	Gabon	Shakthi	Old PSC: OIL – 45, Indian Oil – 45, MarvisPte Ltd -10, New PSC: OIL – 50, Indian Oil – 50
12	Namibia	PEL 0037	Tullow Namibia– 35 (Operator), Pancontinental Namibia–30, OVL – 30, Paragon Oil and Gas - 5
		PEL 30	Eco Oil and Gas Namibia– 32.5 (Operator), Azimuth Namibia Ltd – 32.5, ONGC Videsh – 15, Tullow Namibia – 10, National Petroleum Corp of Namibia (Pty) Ltd – 10
13	Iraq	Block 8, Iraq	ONGC Videsh - 100

Contd...

TABLE 3 (Contd.):

S. No.	Country	Name of the Project	Participating Companies and their Shares (%)
14	Iran	Farsi Offshore Block, Iran	ONGC Videsh – 40 (Operator), IOC – 40, OIL – 20
15	Syria	Block 24, Syria	ONGC Videsh – 60, IPR International – 25 (Operator) Tri Ocean Mediterranean – 15
		Al Furat Petroleum Co., Syria	Himalaya Energy (Syria) B.V. – 33.33 to 37.5, Shell – 66.67 to 62.5 (Operator –Al Furat Petroleum Company)
16	Yemen	82	Medco – 45, Kuwait Energy – 25, IOC-15, OIL- 15
17	UAE	Lower Zakum	ADNOC – 60, Falcon Oil & Gas BV*** - 10, Inpex – 10, CNPC – 10, Total – 5, ENI - 5
18	Israel	Block 32	ONGC Videsh – 25, BPRL – 25, Oil India – 25, IOCL - 25
19	Oman	Mukhaizna	Occidental-45 (Operator), Indian Oil-17, Oman Oil Co-20, Liwa-15, Total-2, Partex-1
20	Brazil	Block BM-SEAL-4, Brazil	ONGC Videsh-25, Petrobras -75 (Operator)
		BC-10, Brazil, Offshore	ONGC Videsh – 27, Shell - 50 (Operator) Qatar Petroleum International - 23
		BM-SEAL-11 (3 blocks), Sergipe Basin	Petrobras (Operator)- 60, IBV 40
		BM-C-30 (1 block), Campos Basin	Anadarko Petroleum (Operator) – 30, British Petroleum – 25, Maersk – 20, IBV-25
		BM-POT-16 (2 blocks), Potiguar Basin	Petrobras-30 (Operator), BP – 30, GalpEnergia - 20, IBV-20

Contd...

TABLE 3 (Contd.):

S. No.	Country	Name of the Project	Participating Companies and their Shares (%)
21	Colombia	Mansarovar Energy Colombia Limited (MECL), Colombia	ONGC Videsh–25-50, Sinopec-25-50, Ecopetrol-50 (Jointly Operated)
		Block RC-8, Colombia	ONGC Videsh – 40 (Operator), Ecopetrol – 40, Petrobras – 20
		Block RC-9, Colombia	ONGC Videsh – 50, Ecopetrol - 50 (Operator)
		Block RC-10, Colombia	ONGC Videsh – 50 (Operator), Ecopetrol – 50
		Block LLA-69, Colombia	ONGC Videsh – 50, SIPC – 50. (Jointly Operated)
		Block GUA OFF 2	ONGC Videsh - 100
		CPO-5, Colombia	ONGC Videsh – 70 (Operator), Petrodorado – 30
		SSJN7, Colombia	ONGC Videsh – 50, Pacific Rubieales Energy (PRE) – 50 (Operator)
22	Venezuela	San Cristobal Project,	ONGC Videsh-40, PDVSA-60(Jointly Operated)
		Carabobo-1 Project, Venezuela	ONGC Videsh – 11, IOC – 3.5, OIL – 3.5, Petronas – 11, PDVSA – 71 (Jointly Operated)
23	Vietnam	Block 06.1, Offshore	ONGC Videsh-45, TNK-35 (Operator), Petrovietnam-20
		Block 128, Offshore	ONGC Videsh- 100
24	Indonesia	Nunukan Block	BPRL- 12.5; PT Pertamina Hulu Energy-35 (operator), PT Medico – 40, Videocon Indonesia -12.5

Contd...

TABLE 3 (Contd.):

S. No.	Country	Name of the Project	Participating Companies and their Shares (%)
25	Myanmar	Block A-1	ONGC Videsh – 17, Daewoo– 51(Operator), KOGAS – 8.5, GAIL – 8.5, MOGE – 15
		Block A-3	ONGC Videsh – 17, Daewoo–51 (Operator), KOGAS – 8.5, GAIL – 8.5, MOGE – 15
		Shwe Offshore Mid-Stream Project	ONGC Videsh – 17, Daewoo–51 (Operator), KOGAS – 8.5, GAIL – 8.5, MOGE – 15
		Onshore Gas Transportation Pipeline	ONGC Videsh – 8.347, CNPC-SEAP – 50.9 (Operator), Daewoo - 25.041, GAIL - 4.1735, KOGAS - 4.1735, MOGE - 7.365
		Block B-2	ONGC Videsh - 97 (Operator), M&S - 3
		Block EP-3	ONGC Videsh – 97(Operator), M&S - 3
		Block: M4	OIL-60, (Op) Oilmax-10, Mercator-25, Oil Star-5
		Block :YEB	OIL:60, (Op) Oilmax-10, Mercator-25, Oil Star-5
26	Bangladesh	Block SS4, Bangladesh	ONGC Videsh - 45 (Operator), OIL – 45; BAPEX - 10
		Block SS9, Bangladesh	ONGC Videsh - 45 (Operator), OIL – 45, BAPEX - 10
27	Russia	Sakhalin-1, Offshore	ONGC Videsh – 20, Exxon Mobil –30 (Operator), Sodeco – 30, SMNG – 11.5, RN Astra – 8.5
		Imperial Energy, Russia	ONGC Videsh-100
		Vankorneft	ONGC Videsh-26, OIL, IOCL & BPRL – 23.9
		Taas-Yuryakh	OIL, IOCL, BPRL – 29.9
		License 61	OIL-50, Petroneft- 50
28	USA	Niobrara Shale Oil/ Condensate JV asset	Carrizo (Niobrara) LLC – 60; OIL – 20, Indian Oil – 10, Haimo Oil & Gas -10
		Eagle Ford Shale acreage in Texas State	GAIL-20

Source: Ministry of Petroleum & Natural Gas (2019)

Oil and natural gas: core to India's foreign policy pursuit

Oil, along with natural gas, is a strategic resource where critical intervention is of imminent necessity for policymakers, diplomats, think tanks, and scholars in India. In the words of the former Prime Minister of India Dr Manmohan Singh, "The quest for energy security in India is the second only in the scheme of things after food security"[30], and since the 1990s, the quest for energy security has become an important element of Indian diplomacy, strategic discourse, and geopolitical relations. As a step ahead, Mani Shankar Aiyar, India's former Minister of Petroleum and Natural Gas, equated energy with country's national security (Blank 2005), and the Indian government has well witnessed and experienced that an energy-insecured country cannot play a sizeable role on global geopolitics and pursue an independent foreign policy. The hope and promises for energy security in India is appealing, yet for a supply-dependent country like India, energy security is no longer a mere desire, but a critical imperative to be met. Even if more energy resources are explored within its territories, the country would have to look abroad for energy needs. To meet energy requirements, India is pursuing various approaches and strategies: diversification of destinations and resources; investment abroad in energy assets; encouraging Indian companies to adopt and execute a comprehensive global vision in their pursuit for hydrocarbon resources. The international component of India's hydrocarbon security has led to much concern abroad, in foreign policy discourse, diplomacy and geopolitics of energy security. This synchronizes what India's decision-makers believe 'an energy-insecure country will be unable to take a rightful place in the global stage as a great power'(Ministry of Petroleum & Natural Gas. n.d., Planning Commission 2006b).

In its international quest, India is engaging the energy-rich countries and regions of the world. Africa, the potential and emerging market, proves significant for robust economic ties. The oil-rich nations, Nigeria, Egypt, Algeria, Libya, are strong partners of India. Central Asia, having geostrategic location along with energy potentials, has turned pivotal for India's bilateral relations and regional approaches. India also has strong relations with West Asia, the largest supplier of crude and natural gas to India. Latin America and Caribbean has been poised with existing potentials and India is looking for improvement of situations and changes in global politics for better trade in Venezuela. Both South China Sea and Arctic resources are in the eyes of Indian foreign policy. The QUAD is a strategic move for India's quest in South China Sea and looking for a sizeable presence in Arctic Sea. Pipeline diplomacy under TAPI, MBI, IPI, etc. is the other energy infrastructures that have added different directions in international relations. The boom in the energy sector under

30 Details available at www.cacianalyst.org/resources/pdf/issues/20050309Analyst.pdf

the Putin government offers better opportunities to bargain with the rest of the world and the Shale revolution in the US has prompted for strategic engagements between New Delhi and Washington. While Arctic energy has posed as a newest destination for the Indian investors to explore, the Shale energy has turned as the latest inclusion to India's international relations.

The Renewable: To What Extent It Can Contribute

Although oil and natural gas constitute crucial role in India's international relations on energy security, yet the demand for clean energy, concerns over environment pollution, and India's international commitment prompts Indian policymakers to look for alternative sources of energy under its energy diversification pursuits and international relations. The world's largest renewable energy expansion programme was launched by India and by 2022, it is intended to achieve 175 GW renewable energy (RE). The 82,588.95 MW (82.58895GW) installed capacity of RE by 31 October 2019 constituted 22.67% of the India's energy basket.[31] Significant to note here, in the last four years starting from 2013-2014 to 2017–18, the RE installation growth in India doubled at 35,000 MW (35 GW) to 40,000 MW (40 GW). With regard to RE production, there has been a progress from 2.6 GW in 2012 to more than 12.2 GW by the end of 2019. In the solar sector, the installed capacity increased by 370% in the last 3 years and set to achieve 100 GW by 2022. Solar capacity has increased by over eight times in the last four years, from 2,630 MW (2.63 GW) to 22,000 MW (22 GW). Likewise, India's installed wind capacity in 2017–18 increased to 34,000 MW (34 GW), which is a 1.6 times increase of 21,000 MW (21 GW) in 2013-14.[32] Further, an Offshore Wind policy notified for a 1000 MW (1 GW) energy installation capacity. Equipment cost that had hindered the affordability scope of the public has been reduced so as to make renewable or solar energy cheaper. For example, solar power tariff has been reduced by more than 75% using plugs and play model. The solar park scheme doubled from 20 GW to 40 GW, solar tariff reduced to Rs 2.44 per unit, and solar pump installations increased nine times, i.e. from 11,600 in 1991–2014 to 1.1 lakh in 2014–2017.[33] From all these RE discussions, it is clear that India is making a stride in this sector; installed capacity is high but the production does not match the installation capacity. No doubt, in future, there will be more demand for renewable energy, but it will not be able to replace the oil and natural gas requirement; what it will do is complement hydrocarbon energy resources so as to reduce oil and natural gas consumptions and lower carbon emissions.

31 Details available athttp://cea.nic.in/reports/monthly/executivesummary/2019/exe_summary-10.pdf

32 Details available at https://mnre.gov.in/sites/default/files/uploads/MNRE-4-Year-Achievement-Booklet.pdf

33 Details available at https://mnre.gov.in/

Paris Agreement: How It will Effect Demand for Oil and Natural Gas

The Intended Nationally Determined Contributions (**INDC**) or Nationally Determined Contributions (NDC) of the Paris Agreement, adopted in December 2015, is intended for reductions in the greenhouse gas emissions under the United Nations Framework Convention on Climate Change (UNFCCC). By increasing an installed capacity of 175 GW renewable energy by 2022, India will be able to surpass its NDC target of reaching a 40% non-fossil capacity by 2022. With a 45% installed capacity from the non-fossil resources by 2030, emissions from the energy sector will subsequently decline by 11%, i.e. 375 tonnes of carbon dioxide equivalent (MTCO_2eq.) (Thambi[1], Bhatacharya, andFricko 2018) from a business-as-usual (BAU) development, considered as a baseline. Since renewable energy is highly cost elastic in the Indian market, a decrease in infrastructures can increase its penetration in the Indian energy market. Taking into account the developmental needs and international commitments, the IEA predicts India is likely to account for a 25% rise in the global energy demand by 2040. Hence, India needs to adopt a multi-pronged strategy that includes both non-renewable and renewable. A mix of decentralized and centralized solutions along with enhanced domestic production of renewable will well augment India's quest for energy security. Since India is determined to achieve its developmental goals with environmental compliances, the country is all set to increase its share of renewable in its energy mix. However, it is crucial for the Indian government to introspect, whether the country's grid is well equipped to handle the supply of renewable energy. It is significant to note that India's energy sector has a lay out for a sea change in its recent energy ambitions by 2022, which includes achievement of 175 GW of installed capacity of renewable, housing for all by 2022, 24×7 power for all by 2022, 10% reduction of oil and natural gas import dependence from the 2014–15 levels, establishment of 100 smart cities, need for clean cooking fuels, and meeting the INDC target as committed in COP21 in Paris (NITI Aayog and The Institute of Energy Economics 2017). However, beyond the projections of 175 GW by 2022, India still has vast and largely untapped potential reserves. The recent estimate implies a 20% increase in the existing potential and measurement. Accordingly, the wind energy constitutes 3000 GW, total solar PV 11,000 GW, biomass 10 GW, and small hydro 5 GW, which could be achievable by 2047 (NITI Aayog and The Institute of Energy Economics 2017). Under the estimates, it is solar energy that assumes much significance to contribute largely for the Indian energy sector.

International Solar Alliance: A Step to Take a Real Headway

Hence, India's new foreign policy and diplomatic approach for the growth of International Solar Alliance (ISA) by the Indian government assumes much prominence for energy security. The ISA, established on 30 November 2015 on the side-line of the UN Climate Change Conference at Paris, 2015, is largely an initiative of India and France, and till date, there are 84 countries who have signed the ISA Framework Agreement, 63 countries have ratified it, and 121 prospective member countries and territories. Recalling the Paris Declaration, the ISA has the shared the ambition to undertake joint cooperation to reduce the expenditure cost of technology, finance the projects, and mobilize USD1000 billion or more investments needed by 2030 for a massive use and installation of solar energy, and pave the way for future technologies.[34] Recognizing the energy-consuming countries, it is an opportunity for the countries lying fully or partially between the Tropics of Cancer and Capricorn to harness natural resources. Being a coalition of solar resource-rich countries, the joint collaborations have been identified to fill the research gaps in the renewable solar sector. However, the ISA is not a replicate or replacement to other international efforts such as International Energy Agency (IEA), International Renewable Energy Agency (IRENA), Renewable Energy Policy Network for the 21st Century (REN21), Renewable Energy and Energy Efficiency Partnership (REEEP), the United Nations bodies, etc. which are currently engaged in rather a comprehensive and sector-specific approach that will establish networks and develop synergies in a sustainable and focused manner. In the energy discourse, the ISA implies a recent shift in energy transition that strengthens the Indian quest for clean, affordable, and sustainable energy security. The Alliance also has foreign policy implications for India to ensure energy security. At the first Assembly of the International Solar Alliance at New Delhi in 2018, Prime Minister Narendra Modi emphasized that if the desire for "One World, One Sun, and One Grid is materialized, the ISA as an alternative to OPEC will not be an impossible task to achieve" (Ministry of New and Renewable Energy 2018).India is working sincerely towards the achievement of the goals of the COP21 through a production of 40% non-fossil fuel-based energy by 2030, and for this objective, it is committed to Rs175 crore investments and expenditure for ISA. By November 2018, India spent Rs 145 crore for building infrastructure, day-to-day recurring expenditure, meetings, and creating a corpus fund (Ministry of New and Renewable Energy 2018). Further, India plans to help set up a global electricity grid that will start with grid network, connecting its neighbouring countries including Myanmar,

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[34] Details available at http://isolaralliance.org/ISAMission.aspx

Thailand, Cambodia, Laos, and Vietnam with the sub-continent as part of an evolving energy security architecture (Bhaskar 2019). The global grid will aim to connect countries such as Myanmar, Cambodia, Thailand, Laos and Vietnam. This can be possible since India has started supplying non-renewable to its neighbouring countries Bangladesh and Nepal, and has been leading for a SAARC electricity grid to meet electricity demands in the region (Bhaskar 2019). However, there are challenges in achieving the objectives of ISA because of lack of proper mechanism for cooperation among the member countries, lack of detail information of the member countries' resource potential, insufficient financial contribution for the organization, and lack of much enthusiasm. However, it is not apt to say that the Alliance is a weak forum. It is in a growth stage and like all other organizations, in the beginning, the ISA is bound to face problems. Its success much depends, how New Delhi effectively leads the organization, and to what extent the energy-consuming countries contribute for the Alliance that will lead to a win-win rhetoric.

Conclusion

India's quest for oil and natural gas have turned pivotal due to growing necessities of Indian economic requirements. As oil and natural gas are strategic resources and there is a global competition for this limited resource, India's energy relations with the countries concerned seems to be complimentary, although not free from global geopolitics and internal troubles of the country concerned. In its quest for energy security, India has diversified its supply basket, and invested in different parts of the world at the Upstream, Midstream, and Downstream sectors of oil and natural gas. Moreover, while going abroad, the country has simultaneously conducted extensive research and investment in the hydrocarbon resources within the country for a comprehensive security arrangement. Taking into account the entire analysis on oil and natural gas through the lens of 2040 Outlook, we can reach at the following conclusion:

1. Since the Independence, oil and natural gas, along with coal, have become the mainstay of India's energy requirement because of their affordability and large-scale availability.
2. Progress in the renewable sector promises for a clean and green energy although not yet able to ensure substantially to reduce or replace oil and natural gas dependency.
3. International Solar Alliance is an international effort of India for renewable energy, yet it has to take a headway.
4. Since oil and natural gas constitute the major sources of India's energy mix after coal, the trend will continue even by 2047, as stated by NITI Aayog.

5. India's growing economic necessities, limited oil and natural gas reserves, and increasing energy consumptions in consequence have necessitated for acquiring more oil natural gas assets abroad and promotion of trade on these resources.
6. The percent of oil may decrease in the energy mix by 2040 but the quantum of crude will increase.
7. The pressing energy requirements and international obligations on climate change have necessitated for increased consumption of natural gas, in terms of both volume and share in the energy basket.
8. Oil and natural gas are strategic resources and key to India's national security. Therefore, these resources will continue as key determinants in India's energy relations and foreign policy pursuits.
9. Diversification and investment in the oil and natural gas assets abroad are the pragmatic foreign policy approaches that the country has pursued to ensure its quest for energy security.

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REIMAGINING INDIA'S ENERGY FUTURE: CHALLENGES, OPPORTUNITIES AND COOPERATION PATHWAY

CHAPTER 6

Redesigning India's Energy Strategy for the Post-COVID-19 Era

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Abstract

The primary challenge presented by the COVID-19 has been adversely affecting the momentum in building the clean energy infrastructure in India, due to the disruption in the international material and equipment supply chain. Secondly, the surge in emissions after a temporary fall in the initial months of COVID-19 has presented an alarming scenario of emission-intensive energy consumption in the country and highlighted the need to limit fossil fuel usage. The article highlights that despite these challenges, India has the potential to redesign the domestic strategy in securing a clean energy future. The country's call for strengthening the domestic economy and enhancing self-reliance are critical policy steps that will gain relevance among the other Asian countries as well. The chapter further elaborates that India's Triple-R approaches that consist of 'response', 'recover' and 'redesign' initiatives are largely in tune with the global response, which can also set guiding examples for the developing economies in Asia.

Introduction

India's ambitious target of achieving 175 GW of renewable-installed capacity by 2022 and 450 GW by 2030 face newer challenges owing to the pandemic-driven disruption in the supply chain. These impediments include disruption in the raw material supplies for the solar energy industry, which are causing delay in renewable installations, and stalled investments in low carbon technologies and energy storage. Immediate policy responses to address import dependency have come in the form of proposals to levy import tariffs on solar modules and announcements to diversify resource explorations through open acreage policies. However, a long-term strategy should focus on meeting clean energy goals and reducing import dependency, and also the need to incorporate strategies that effectively decouple economic growth and energy. Some of the policy tools that can help in achieving relative decoupling include demand-side decarbonisation and enhancing energy efficiency through technology innovation. Furthermore, renewable developments in the post-COVID-era should advance further to increase investments in off-grid and decentralized renewable installations and facilitate system integration of various renewable energy options.

A historical drop in carbon emissions and a steep decline in the fossil fuel prices during the initial months of the lockdown have served as potential opportunities for accelerating India's energy transition trajectories. A notable increase in the share of renewables in the electricity mix has also been recorded owing to uninterrupted supply of the 'must-run' renewable power plants during the lockdown period. The emissions can be kept under check only when greater momentum is given to climate mitigation actions. However, though climate mitigation actions are critical, it will be a challenging task to keep the momentum on as India's economy is in a downturn and big budget deficits are being made. One of the major motivations to bolster energy transition in the wake of the post-pandemic world for India might be the lessons learned from the flexibility and resilience of renewable energy in comparison to fossil fuel. The country needs to urgently focus on and bring policy actions on its major reliance on fossil fuel imports to meet its energy demand and its dependence on international supply chains for meeting the renewable energy installed capacity.

While India's development trajectory indicates that it could overtake Japan to be the third largest economy by 2050, this also comes with greater responsibility as the country will need to demonstrate adequate actions that promote climate mitigation and clean energy development in tune with sustainable and resilient recovery. In this regard, India's Atmanirbhar initiative (self-reliance) also presents a newer pathway for redesigning domestic policies, in tune with the changing global order. It also sets an example for sustainable and resilient recovery for the developing economies in the Asian region.

The structure of the paper is as follows: First, the paper elaborates the challenges India faced with respect to energy security, in the wake of the pandemic and the gravity of these impacts particularly faced by the renewable sector. Further, it discusses a brief survey of literature which focuses on the potential for recovery of the energy sector, in general in India. This section also gives thrust to the argument that the recovery needs to be sustainable. The paper then delves into India's policy initiatives surrounding the 'Triple-R framework – response, recovery and redesign'[35] and highlights the possibility of offering valuable good practices to other developing countries in Asia.

COVID-19 Impact for India: Energy Security and the Renewable Energy Sector

The impact of the pandemic, apart from on the economy and human health, is also seen on the renewable energy sector as well as on the climate mitigation imperatives of the country. The pace of installation gets greatly affected when there is a break in the supply chain for the renewable energy equipment and machinery. This makes it essential that the

[35] This paper uses an approach of Triple-R- Response, Recovery and Redesign to study and analyse countries policy responses to the pandemic and related impacts on their respective economy. The approach is based on the paper: MORI, H., Implications of COVID-19 for the Environment and Sustainability (Version 2): Perspectives from the Triple-R (Response, Recovery, and Redesign) Framework.

country find alternative supply sources to replace imports. On the climate front, COVID-19-induced economic slowdown has presented notable impacts. In the initial months of the COVID-19 outbreak in 2020, as a result of the nationwide lockdown, businesses and industries slowed down operations and emissions from the transportation sector were drastically reduced. However, when the country was reopened, air pollution as well as emissions came back to surging levels in the subsequent months.

More than understanding the interim reduction of global emissions, energy security concerns have come to the forefront in the wake of the pandemic, with respect to uncertainty of reliance on international energy links in ensuring energy supply. As most parts of the world went into their respective phases of confinement in early March 2020, the global energy demand during the first quarter of 2020 fell by 3.8%, with notable steep declines seen in coal and oil consumption demand (IEA, 2020a). Before the pandemic, international energy interactions focussed on ensuring building diversified value chains in the supply of energy for a country. A break in this supply chain for the new and renewable energy equipment and machinery posed a critical challenge to the pace of installation, and brought the sector to rethink energy security in totality, whereby it can be more geography independent. The pandemic has brought forth the need for a country to find alternative supply sources to replace imports by cultivating self-sufficiency and maximizing employment of indigenous technologies and resources. With the impact of the pandemic still unfolding, a long-term system of understanding energy security of a country and redefining its nuances, keeping in mind the present predicament, has become utmost important.

The primary reason economies were propelled to transition to renewable-dependent energies from coal-intensive ones, apart from ensuring lower emissions is the modern academic concern around the discussions on the prevalence of energy poverty, concerns of energy justice, and the impetus to increase energy access to people at affordable rates. The ongoing pandemic has made it more than obvious in that regard. Another important characteristic of the integration of renewables in the energy mix is the benefit of democratisation of the process of energy generation via the establishment of individual, domestic bases of the likes of solar and wind installations. When properly administered, this can give individuals the benefits of both using clean energy and selling back the excess energy to the grid, thus providing an unprecedented flexibility of energy choices to households (Das, 2020). The 10-year action plan as part of *The Draft National Electricity Plan* (NEP), introduced by the Ministry of Power of India highlights its commitment towards the above (Kumar. J & Majid, 2020). In this context, it must be noted that renewables have, over the time in India, become one of the primary sources of power generation. At the time of writing, 101 GW of India's power demands are met through renewables (CEA, 2021).

In the same token, however, one cannot overlook the fact that India's energy demand and its progress towards renewables is fed through imports. It becomes imperative that one take a keen look into how much of renewable technology is dependent on international import and how has the sector been affected by the pandemic-induced disruption to trade. While studies have found the energy sector of the country to be surprisingly flexible and resilient in the wake of the global pandemic induced by the COVID-19, thanks to time tested installed hydropower capabilities of India, in terms of new renewable technologies such as solar, the primacy on import of technology from abroad is something that came to be hard hit by the pandemic. Most of India's import of renewable technology, be it in terms of equipment or machinery, comes from China. Around 88% of the imports for the solar power sector with respect to technology, equipment and machinery comes from China (Tongia, 2020). In this context, several ongoing projects have been slated to face severe delays and production slowdowns because of a decline in imports of equipment such as solar modules, cells, etc. by 70% (Gupta, 2020). It is expected that while the imports of machinery have largely been affected, like the complete stoppage of the import of solar panels from China due to pandemic-induced trade restrictions, and delay in the commissioning of new solar and wind power plants in the country, the impact of the same shall continue to peril the renewables sector of the country for at least next few years (Pradhan, et al., 2020). Further, as faced by other industries and economic sectors, the renewable energy sector, in the wake of lockdowns, also saw reverse migration of the labour force who worked in installation and power projects that were stalled. Similarly, technical problems were witnessed in the management of projects of new wind-power run plants, such as delay in processing land acquisition required for installations and paucity of requisite finances for the projects. These led to delay in achieving the targets set by the Indian government in accomplishing a smooth transition to renewables. In the same regard, the drop of the rate of the Indian Rupee vis a vis US dollar to an all-time low makes India even more vulnerable to possible trade deficits in the future with regard to technology imports (Vermani, 2020). Further, even while the dependence on coal reduces over time, the need to import oil and gas is slated to increase in the next few decades. While there is a push to transition from coal-based power plants into gas-run ones, around 50% of the country's natural gas demands are met by imports, with 23% of the current power demand of the country met by natural gas (Financial Express, 2020a).

The power sector of India has brought to light the dichotomy facing the energy sector in the country. As there was a reduction in demand for electricity from the industrial sector during the lockdown, the coal-intensive power generation was made to run in low capacity. On the other hand, the renewable sector was made to run on a 'must-run' basis, and powered the household sector of the country alongside hospitals during the pandemic. However, even while the cost of renewables comes down over the years, the transition of energy from fossil intensive to renewable services is something that would involve price rise. How the government supports this transition with financial aid to the consumers while maintaining the importance of the sector among investors remains an important element. There is an urgent need to make the state government-run installations of power to become self-reliant, despite the power grid of the country being a centralized facilitating financial sustenance (ET Energy World, 2020).The overall recovery of the energy sector of India is expected to follow from its economic revival. With the subsequent resumption of economic activities in the country, demand for energy is slated to grow eventually. For the rest of the year being winter months and India being a tropical country with not much necessity for electricity powered heating mechanisms in large part, the demand for power, at least in the household sector is to remain more or less the same. In the same token, the demand for power in the ensuing summer months of the country is to grow from the household sector.

A boost towards the initiation of renewables in the energy mix has arisen from the growth of demand for energy in the industrial, economic, agricultural as well as the domestic sector of the country. The electricity sector of the country is still growing in order to make electricity accessible to all. In this context, while analysing the challenges faced by the renewables sector of the country during the pandemic, one must take note of the fact that it is the resilience of the hydropower sector in the time of this crisis, that has, kind of, shown the direction the rest of the renewable options might take in its participation in the energy mix of the country. Being the world's third largest consumer for electricity, the hydropower sector of India is the sixth largest in the world.

The import induced crisis particularly in the solar sector of the country has been further recognized by the government (the MNRE) and more time has been given to the companies that have already commissioned projects to meet the targets and relief from penalties (Vermani, 2020). Again, the RBI's announcement to delay the loan repayment for the companies involved in launching new solar projects by a quarter can be seen as a way in which the sector might gain some financial respite in the hours of need to rejuvenate itself. The government has also specified solar power to be an essential service, allowing necessary movement of related commodities that will boost the sector (Gupta, 2020). While the pandemic has exacerbated the financial distress of the state regulated power distribution companies (discoms), these have rather been in crisis for some time now. Because of the temporary slowdown in the industrial sector, these discoms have seen loss of income. The government has given temporary financial relief to these discoms by lowering their credit requirements.

The structural changes that need to be brought to notice with regards to the renewables sector in India is something that has been imminent for the sector, irrespective of the pandemic. These burdens or impediments for the sector have been there for some time, while the pandemic has only made these stark, forcing us to rethink on an urgent basis. A time-bound action on these pointers is sure to boost the sector and help it be resilient towards future shocks of similar kind. There are several statements in academia that make the argument that the recession of the government from the management and the operation of renewables in India, coupled with the independence of the market, will remove impediments in the path of crisis. However, one cannot but argue that if there is one sector that has been the hardest hit by the global pandemic, it has been the economic sectors that are unregulated by respective governments. It is the private sector, in other terms, that has come to bear the brunt of the economic crisis which the pandemic has brought about. If the same logic might be applied to the energy sector of any country, in general, and India, in specific, it can be argued that greater involvement of the government in the sector is something that might play restorative performance. The Indian government has already shown zeal in the same regard. Despite the privatization of a large section of the energy sector, the tight control of the regulative and managerial indices has arched the sector towards development oriented with commitments of poverty alleviation and the promise to ensure energy access to all. One must take note of the systematic undertakings by subsequent Indian governments in committing to energy transformation in the first place. For a developing country, the burdens of maintaining lower emissions while continuing to cultivate economic growth is a tough balance. While there are arguments in favour of percolation of a democratized, transparent and decentralized method of energy generation with respect to renewables, a tight grip on the management of generation, distribution and pricing of energy by the government is something that would rather benefit the country. The delays in management, due to bureaucratic hurdles, common in developing countries like India, have come to be replaced by the intent of governments to the commitment of reaching climate goals. This can be better met with the introduction of cost-effective tariff rates, as introduced to the customers, and simplification and increased transparency of the tariff rates keeping the end in mind.

Review of Literature: Energy and COVID Impacts

Around 75% of India's power generation continues to be based on fossil fuels. In the first six months of 2019, a study by Myllyvirta suggests that there has been a 17% increase in electricity generation via wind, 30% by solar, and 22% by hydro (Myllyvirta & Dahiya, 2019). This definitely throws a hopeful light in terms of bringing in enhanced engagement of renewables in the power mix, cutting down on the overcompensating expectations of the coal-driven energy sector (power sector) slowly but steadily, playing to the reasonable demands of the same, starting with restricting or limiting the building of more fossil fuel-dependent power-generation plants (Myllyvirta & Dahiya, 2019). India has announced its intention to increase its renewable energy capacity to an ambitious expectation of 220 GW by 2022 from the existing clean energy capacity of 134 GW, alongside a promise towards increased use of advanced technology and a steady decrease in power generation (PTI, 2020).

According to a 2017 study by IRENA, the socio-economic make-up of India is set to have implications on the increase and pattern of increase in electricity demand of the country. The study expects that while the income of the vast population of the country remains low, rapid increase in industrialization and urbanization, coupled with a steady increase in the population, is supposed to propel energy demand in the country with electricity demand slated to almost triple by 2030 and a heavy reliance on fossil fuels to meet this demand (IRENA, 2017). The study also mentions that despite this growth in population and the demand for electricity, a large section of the population continues to suffer from energy poverty, whereby their need to have access to clean and affordable energy is yet to be achieved (IRENA, 2017). The energy poverty consideration of the consumers of the country must be kept in mind while charting out the trajectory of energy policies. The major driving force behind the study to understand the possibility to enhance the participation of renewables in the energy mix of the power sector of the country, has been to understand the country's intention and political will to alleviate energy poverty. The IRENA study maintains that the engagement of renewable energy in the power mix of India will continue to grow with the possibility of achieving 60% of its capacity (IRENA, 2017). However, since the varied options of the renewable power generation sources in the country, one must take note of the requirement of thoughtful planning and programmed strategizing for the creation, maintenance, financing, transparency in management and conservation of the renewable-generation units (IRENA, 2017). The study also predicts that the increased inclusion of renewables in the power mix would bring about larger savings for the sector, increase energy efficiency alongside 'ease power supply constraints', making it partially immune to disruptions caused by international relations and 'geopolitical shocks', and create jobs (IRENA, 2017).

Rapidly growing economies such as India and China have been denoted as the chief reason for the rise in greenhouse gas emissions and the global crisis in climate management. It has been enumerated that a successful decoupling of economic growth trajectory from carbon emissions might be one of the effective strategies to bring about a balance whereby 'economic growth can run independent of emission growth' (Wang, et al. 2018). Theoretically, this provides an alternative perspective in the study of global greenhouse emission understanding, whereby decoupling of emissions and energy demands from the economic development of a country might help in a more objective understanding and subsequent policy implications on the part of developing economies, especially with respect to understanding of stowing the emission burden of the world alongside the drive to achieve economic progress.

There is the urgent need to establish transparent and tangible pathways for the larger participation of renewables in the energy mix of India. This includes enforcement of sustainable land acquisition policies, conducive banking and financing mechanisms for the sector and creation of knowledge building and systematic permeation of education exercise by the state alongside the important part of grid strengthening (Saxena, 2017; IRENA, 2017). This might create a conducive environment for businesses to invest in the sector for the long term, making it affordable and sustainable for the consumers as well. This is a delicate balance that the state must intend to create, given the socio-economics of the country, keeping in mind that a large amount of fuel choices made by the consumers comes from the generic availability of non-renewable and non-sustainable fuel options around them. Permeation of knowledge among the consumers on the consequences of their choices and the long-term benefits of choosing renewables over non-sustainable energy resources might increase the possibility of sustained inclusion of renewables in the energy mix of the country.

A 2017 study by TERI projects that the demand for electricity in the next few years is slated to grow not only with the increase in the purchase capacity of the consumers, but also with the increase in the quality of electricity provided and stability of the electricity grid in the household electricity sector (Saxena, 2017). The study also very interestingly points towards the possibility of a dip in the demand for power consumption in the wake of increased participation of renewables in the mix, given the surge of competition in the market driving the cost of access to electricity higher for consumption (Saxena et al. 2017). This is particularly true of the electricity consumption pattern in India and cannot be ignored while analysing the potential of renewables in the power sector of the country.

According to the International Energy Agency(IEA), 'India is making great strides towards affordable, secure and cleaner energy' with 750 million people currently having access to electricity (IEA, 2020). The IEA, however, points out that much of the electricity generation has been dependent on fossil fuels. The study says that while the emission intensity of India's gross domestic product has decreased by 20%, the overall carbon emissions of the country continues to rise (IEA, 2020). On the flip side, the study highlights that the emission rates in the country have not grown much over the years, corresponding with the rapid increase in the rise in the GDP of the country. In this context, India has been able to generate and distribute 84 GW of renewable energy through grid connection in 2019 itself (IEA, 2020). However, lack of a general and coordinated national energy policy in India has been denoted to be the main impediment towards coherent implementation of sustainable energy security.

Restructuring India's Energy Sector: Triple-R Approach

Renewable energy transition in most countries of Asia, including India, has underlying policy motivations to ensure equitable last-mile energy access, energy security as well as to achieve climate mitigation targets. India has shown remarkable progress in the implementation of climate-positive policies. It is the only developing economy in the G20 countries to show 'high performance' in maintaining a well-below 2°C compatibility scenario (Burck, *et al*., 2020). India's climate leadership and diplomatic outreach can be realized by the progress of its proactive partnerships such as the International Solar Alliance (ISA), the Coalition of Disaster Resilient Infrastructure (CDRI), and more. Furthermore, as a Mission Innovation (MI) country, India's national efforts and multilateral engagements to meet climate targets by leveraging innovation and clean energy technologies have been exemplary.[36] Having said that, the existing institutional mechanisms such as Clean Energy International Incubation Centres and IREDA's 'Green Window' can further be effectively utilized to attract private and international investments in clean energy technologies.

India's record of climate commitments provides a diplomatic space for its engagement in the South Asian region to address the regional vulnerabilities that the countries are prone to. Given the interlinked problems posed by the pandemic and climate change, it is essential to construct a South Asian perspective on green recovery and climate change (Saran, *et al*., 2020). Regional and neighbourhood diplomatic processes can possibly foster 'co-innovation' that is in the form of 'a collaborative and iterative approach of jointly innovating, manufacturing and scaling up' of clean energy technologies (Janardhanan, *et al*., 2020).

Despite the progress made so far at the institutional level, the COVID-19 crisis has necessitated restructuring of the otherwise business-as-usual policy imperatives. The discussion here is built around the Triple-R (Zusman, *et al*., 2020; MORI, *et al*., 2020) approach which encompass the three key elements: *Response, Recovery and Redesign*. While the response phase focuses on the immediate policy and health sector-related responses, the recovery focuses mostly on economic plans that include stimulus packages and policy measures to set the country towards normalcy. The redesign phase will need to focus on the policy as well as institutional restructuring with a view to build in the element of sustainability into the country's long-term developmental policies.

[36] For more information on the plans and pledges under Mission Innovation, please see - http://mission-innovation.net/our-members/india/plans-and-priorities/

Response: India's Responses to COVID-19 Impacts and the Extent of Progress in the Energy Sector

As an immediate rescue measure to the crisis, the Government of India announced a substantially huge stimulus package under the 'Atmanirbhar Bharat' (self-reliant) scheme. It amounted to about 9.3% of the country's GDP. The Atmanirbhar Bharat focuses on resurgence under five pillars, namely economy, infrastructure, system, demography, and demand[37] (EconomicTimes, 2020). Various measures such as announcing collateral-free loans, insurance covers, liquidity concessions, compliance reforms to boost the Ease of Doing Business (EoDB), and technology-driven capacity building programmes are proposed under the scheme, through a period of five phases.[38]

When it comes to a 'green' response in the energy sector, besides facilitating a one-time liquidity infusion for the distressed DISCOMs during the emergency, the stimulus package of the government has not yet provided any direct instrument for a sustainable recovery of the energy sector. However, the government's immediate response to the situation by labelling renewable-generating stations as 'must run' has considerably directed commendable shifts towards cleaner energy access. Following that, in June 2020, the NITI Aayog published a research report envisaging principles to build a cleaner energy economy in a post-COVID-19 scenario (NITI Aayog, 2020). The report recommended four principles for a clean energy scenario: (1) investments in low-cost energy solutions, (2) building resilient energy systems that would withstand disasters and unforeseen crisis, (3) prioritizing efficiency and competitiveness by devising circular economy options, and (4) promoting social and environmental equity (NITI Aayog and Rocky Mountain Institute, 2020).

In similar lines, as a measure to achieve self-sufficiency, the Ministry of Renewable Energy (MNRE) has made proposals to states for setting up manufacturing hubs across the country. The government has identified solar PV and advanced battery cells into the list of new 'champion sectors' to attract investments. As a part of the structural reforms under the Atmanirbhar Bharat, an overhauling tariff policy has been announced that seeks to address the issue of consumer burden, envisaging a long-term sustainability of the sector.

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37 The five pillars and the different phases of Atmanirbhar Bharat are outlined here - https://www.india.gov.in/spotlight/building-atmanirbhar-bharat-overcoming-covid-19

38 For further details on the announcements under Atmanirbhar Bharat, please refer to the report from the Ministry of Finance, "Atmanirbhar Bharat – Progress so far"- https://cdnbbsr.s3waas.gov.in/s3850af92f8d9903e7a4e0559a98ecc857/uploads/2020/10/2020100182.pdf

Considering the immediate priorities of responding to the job losses and reducing import dependency, the government launched an auction process for commercial coal mining. As a move 'turning crisis into an opportunity', this announcement came as a part of the coal sector reforms that would enable the country to competitively produce domestically (PIB, 2020).

Recover: To What Extent the Recovery has been Contributing to Clean Energy Transition in India

Stimulus packages that solely focus on liquidity and short-term rehabilitation of livelihoods run the risk of succumbing to the fossil fuel systems, as was observed not only in the government's recent coal sector reform but also in various national policies during the previous global economic crises. Thus, unless rescue packages give space for long-term investments in clean energy infrastructure, the climate pledges of nations will be further delayed. In an analysis of how governments responded to the COVID-19 crisis, it was observed that developing economies announced stimulus packages that fostered environmentally intensive industries rather than designing green trajectories (Salazar, 2020).

This being on the domestic end, while responses to the shock through stimulus packages may relieve the economy in the short-term, medium- and long-term recovery will be largely dependent on international fuel prices as well as global economic revival (Sen, 2020). For a net energy importer like India, fiscal security remains a crucial determinant of energy security and transition. Falling oil prices and a hit in the fossil fuel consumption demand, coupled with decade-low prices of renewables, have created a potential response scenario where increasing investments in cost-effective renewables are evidently imminent.

Not discounting the fact that India is already ahead in realising its Nationally Determined Contribution (NDC) targets for 2030, clean energy transition in India is majorly hindered by the lack of a binding plan for phasing out coal. While simultaneously increasing the deployment of renewables over the years, the government's move towards the acceleration of commercial coal mining shows that energy policies are still ambitious on coal-based power production. Despite the rapid growth in the share of renewables in electricity, coal occupies a substantial 52.6% of installed power supply (CEA, 2021b). Moreover, even if the country's energy landscape accommodates the increasing share of renewables, a cut in coal production may consequently disrupt power generation damaging the domestic economy (Janardhanan & Tamura, 2020).

Following the 24x7 'Power for All' electrification goal that has been achieved in 2019, it is estimated that electricity demand will increase as the economy recovers. It is projected that by 2050, the total electricity demand will increase fivefold to around 5500 TWh. While electricity access has been made a functioning reality, the existing 'low-level equilibrium trap' of 'poor quality, poor payment, populist politics' in the distribution of electricity necessitates immediate policy measures and subsidy reforms (Swain, 2020). Several factors such as stressed DISCOMs, the dominance of coal-based power plants, and reluctant investments for newer renewable deployments make a cleaner electricity transition difficult.

A policy for public ownership of renewables shall ensure not only the development of the clean energy sector but also the formalization of the incurring job transition and thus an equitable distribution of social benefits (Roy, et al., 2019). Besides shifting away from coal, implementing subsidy reforms and regulating tax structures in such a way to ensure the competitiveness of renewables are critical to a post-COVID-19 recovery process. Earlier in 2018, the National Electricity Plan (NEP13), realizing the overcapacity and falling utilization rates of coal-based power plants, had announced the retirement of old and polluting coal plants of 22,716 MW capacity before 2022 (CEA, 2018). The retirement of such plants will not only address the environmental externalities of coal but also create fiscal spaces for a clean energy transition. The NEP13 also aims to increase the share of non-fossil fuel-based resources in India's electricity mix to 56.5% of installed power capacity by 2027.

The IEA, in its country report on India, has welcomed the opening up of coal mines to private entities, as it would enhance the economic efficiency and operational flexibility in the sector (IEA, 2020a). However, India's policy conundrum lies at the diverging ends of achieving decarbonization while at the same time addressing the socio-political consequences of coal transition (Janardhanan & Tamura, 2020). The dilemma has become crucially problematic now, aggravated by the circumstances of post-pandemic ambitions to domestically meet the reviving electricity demand.

Redesign: Need for Redesigning Energy Sector Policies to Make a Sustainable and Resilient Recovery

As mentioned in the previous sections, the temporary fall in carbon emissions has helped to spot the major contributors in emissions, i.e., transport, industry, and power sector. In the transport sector, existing policies such as the FAME scheme (which is now in the second phase of implementation) have already envisaged a sustainable way of mobility. Aiming for a 25% electric vehicle (EV) mobility in road transport by 2030, the government has laid out for EV highway corridors. Further improvements in this clean mobility trajectory should focus on exploring ways to reduce EV battery costs and developing hydrogen energy infrastructures. Furthermore, in an encouraging step towards clean mobility, India has launched the Decarbonising Transport of Emerging Economies (DTEE) project in association with the International Transport Forum (ITF) to explore pathways that can potentially reduce carbon emissions from the transport sector (International Transport Forum, 2020). The Ministry of Railways has also announced plans to achieve 100% electrification by 2024, and consequently the ambition of becoming a net-zero emitter by 2030. While decarbonization of the Indian Railways is estimated to be cost-effective, various policy lacunae in state-level implementation of net metering policy come as a major impediment to a successful renewable energy transition in the India Railways (Konda, et al., 2017). Moreover, there is a need for state-level cooperative mechanisms to be put in place for an effective land acquisition that can be used for solar and wind installations.

For a cleaner power supply in India, the IEA has identified areas of potential innovation such as small modular nuclear reactors, flexible operation of gas-fired power plants, and effective deployment of carbon capture, utilization, and storage (CCUS) technologies (IEA, 2020b). In addition to the aforementioned areas of diversification of power supply, realigning priorities towards decentralized and distributed renewables (DRE) is crucial at this juncture. Despite the budgetary support through policies, such as the Kisan Urja Suraksha Uttham Mahaabhiyan (KUSUM) and the Grid Connected Solar Rooftop Programme, the progress of off-grid installations and DRE deployment declined during the lockdown (Koundal, 2020). At present, distributed renewables contribute to a meagre 5% of the total installed renewable capacity in India. It is estimated that upon the deployment of the government's 500 MW mini-grid target, the DRE sector will provide more than 190,000 formal jobs and 210,000 informal jobs by 2022–23 (PowerForAll, 2019). Thus, a redesigning strategy should ensure that there are significant measures such as credit guarantee schemes and subsidies for facilitating DRE deployments and strengthening local value chains.

In their report concerning the clean energy economy in a post-COVID-19 India, the NITI Aayog and the Rocky Mountain Institute have proposed a strategic framework for utilizing the stimulus investments to reap impactful green recovery. Designed in three phases, 'Fix It', 'Replace and Extend', and 'Transform and Grow', the report recommends temporal increments in the way the investments can be used to meet clean energy challenges. The phase of 'Transform and Grow' focuses on long-term impacts of the stimulus package and addresses how the investments will drive decarbonization beyond temporarily 'fixing' the disrupted economy. A few of the thrust areas that are to be considered while envisaging a long-term transformational (re)design strategy include reforms in electricity distribution, scaling of energy storage, and development of an indigenous base for the production and supply of renewables (NITI Aayog and Rocky Mountain Institute, 2020).

Even when a redesign strategy promises to achieve greener transformation, ensuring resilience to the diverse modes of energy systems is a key policy challenge to consider. Given that long-term decarbonization is possible only through the employment of newer forms of clean energy innovation and technologies, India in its long-term strategy should provide space for conducive market mechanisms that will allow technology collaborations to efficiently cater to the expansion of the existing domestic innovation base. With ambitious plans touching various areas such as electric vehicle mobility, sustainable cooling, and CCUS, India must move beyond material and equipment imports and towards strengthened multilateral co-operations in knowledge transfers and utilization of internationally acclaimed clean energy technologies. However, higher capital costs of installation, and, thus, the reluctance of imparting alternative technologies to the conventional systems have hindered technology absorption to a greater extent. Thus, if India considers integration of advanced technologies for the long term, it is expected that a redesign strategy would provide market incentives across sectors to alleviate the fears of technological risks and a reinforcement of legal and institutional values to achieve harmonization at par with the global market standards.

What Lessons Can Asia Learn from India?

While nobody pre-empted the pandemic in any form and the disruptions it would bring forth for economies across the world, the availability of an Integrated Energy Policy (IEP) in place, under discussion, for India. It has been a motivating factor, providing an overarching guidance towards cultivating energy self-sufficiency for the country, given the recognition it gives to the primacy of exploiting renewable energy, even while the economy continues to rely heavily on fossil fuels. India has been embarking heavily towards the route of an integrated energy 'approach', beyond the IEP, that would ensure supply chains for energy transition in the country, so that the energy sector does not face a similar crisis, as brought forth by the pandemic, in the years ahead. More than the IEP, it is the integrated energy approach that might come to form a bedrock on which the recovery of the energy sector of the country might rest and build forth, with adequate attention given to guidelines to build self-reliant transition towards renewable energy. While it is recognized that the reliance on fossil fuel cannot be eliminated in one strike, the focus on energy efficiency is something that the country might come to pay attention to. An augmented role of nuclear and hydropower is an approach that can be counted on by India, while building a self-reliant energy transition. Adequately addressing fiscal policies that are tuned towards balancing externalities induced energy insecurity, especially for the renewables sector, long-term but targeted subsidies for consumers as well as investors of the sector, and regulating taxes so as to make a level playing field for investors as well as consumers in the sector is a pathway to creating an integrated energy approach for India. Thus, there is a need for India to reassess its energy policy and develop an integrated energy approach that re-evaluates its trajectory of fossil fuel dependence and increased utilization of other traditional resources, towards renewables. Further, while the IEP understands that energy security of India does stem from managing diversification of its energy portfolio via continued reliance on imports, avoiding geopolitical impacts on it via cultivating diplomatic goodwill with other countries, the integrated energy approach lays primacy on the need to reassess this import reliance altogether, with the focus on building and strengthening indigenous resources and technologies, as well as harnessing geographical independence in this regard. This kind of approach to energy security has been on the forefront of the current government of India, whereby, there has been an overall target on improving the energy sector's drive towards solar and wind power. While it is true that technology for this transition has also been fed primarily by imports, then again, one cannot argue that anyone saw the pandemic coming. In this regard, however, the country's push towards 'Atmanirbharta' is something that can be viewed with promise, with regards to the development of indigenous technologies to bolster the transition to renewables and other sustainable sources of ensuring energy security. This approach is something that the rest of Asia can take a lesson from and inculcate in their own way and form, conducive to their own context.

Over the last four years, India has doubled its renewable capacity (Kumar & Majid, 2020). Further, several small-scale initiatives have benefitted from government support and in turn lead to more investments from private sector. The growth of the energy sector in India has always and, must in the future as well, go hand in hand with the developmental imperatives of the country, keeping in mind the affordability of the energy services. While private investment in the field must be encouraged, rapid privatization and absolute independence of the private sector in the renewable sector will bring about an unfettered rise in the prices of power, making the consumers choose other unsustainable sources of energy. This rather fails the purpose of the transition in the first place. Thus, along with the political intent of emission reduction, in the post-COVID-19 era, the government must not lose sight of the long-term goals, making financial incentives to the power producers alongside subsidies to the consumers. This is a herculean task that must be brought hand-in-hand with systemic changes in the structure of power production and distribution. There must, hence, be a delicate combination of some sort of a balance between government-regulated standardization along with a boost to self-reliance and independence to public–private partnership along with a more efficient national-, regional-, and state-level coordination, which will give the much-needed boost to the sector.

Finally, what has surfaced in the pandemic assault on the energy sector of the country has been the exposure of the vulnerability of some renewable technologies over the resilience of the other. While the hydropower sector has sailed in the crisis, the one that has been hit hard by the same is the solar power sector. This is an important piece of information, given the structuring of the sector and the angling of the development of indigenous technology. Further, India has invested in the development of the hydropower sector of the energy sector since the formation of the sector itself, while the primacy of solar as a viable alternative for power generation is rather new. Planned development in the latter sector, keeping in mind the importance of the development of indigenous technologies, can shield the overall energy sector from import dependence in future.

The post-COVID-19 redesign aspirations across the world, in this regard, can be guided by the policy lessons from the governments across the world. As a measure to collectively address the systemic challenges of both the COVID-19 pandemic and climate change, the Ministry of Environment Japan has announced an initiative called ‘The Platform for Redesign 2020’ to share information and policy perspectives on various climate and environmental measures that are to be considered alongside the COVID-19 crisis.[39] Multilateral platforms such as these facilitate countries to effectively redesign and transform their policies towards a greener recovery.

One of the ways forward towards the rejuvenation of the energy sector in India has been the concentration of discussion around building an ‘Atmanirbhar Bharat’ or a self-reliant India. Among the key elements that are being looked into, within the premises of the idea is the development of trained personnel, upgraded machineries and the advancement of required research and development needed for the improvement of the energy sector of the country smoothing the transition to renewable capabilities. The intention, in this regard, of the government is to play the role of an active enabler in the creation of a situation pertinent for the growth and development for the domestic manufacturing of capabilities for enhanced participation of renewables within the energy sector.

Conclusion

With regard to the energy strategy of the country, one may note that the policy directions will have two strands in the years to come. These include continued importance attributed

[39] For more details about the initiative, please visit - https://platform2020redesign.org/

to renewable sources and a possible focus on Net-Zero emissions for the nation. In the context of renewable energy targets, the country has already laid out a plan for expanding the renewable energy installed capacity from 175 GW in 2022 to 450 GW in 2030. This can be a challenging task if India does not develop adequate material and equipment supply lines from within the country. India's plan for strengthening the domestic industry will be a critical step. The promotion of production of critical equipment and machinery for the renewables sector will not only contribute to the development of the renewable sector but also will ensure strengthening of the domestic economy in the long run. On the climate front, top-emitters including the US and China have announced their respective targets for becoming net-zero emitting countries. Being the second largest emitter in Asia after China, India will need to plan for substantially limiting greenhouse gas emissions. In the years ahead, the biggest challenges for India will be to continue to ensure clean energy access for the population and to revive and manage the economic growth trajectory. These will demand redesigning domestic policies in order for the country to move away from a fossil fuel-based economy to a more sustainable, clean energy mix.

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CHAPTER 7

Just Transition in India – A Double Doughnut Framework

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Introduction

The mineral economy historically and globally has been central to the development framework of human evolution and the local economy for years. Evidence has been found within the fabled Harappan civilization and their large-scale use and consumption of coal for energy purposes (Joseph 2021). Coal sat at the very top of the evolution tree in the 18th century, when it became central to the phenomenon that later came to be known as the 'Industrial Revolution' (Ville 2016). The impact of coal as an entity and civilization creator cannot and should not be undermined given the spillover effect it has had within the overall economic process. However, coal has now become one of the foremost contributors of climate change and is fast becoming the mineral that countries all over are trying to run away from in order to manage the growing climate crises. India remains central to the global coal-based sustainability catastrophe; with a total emission of more than 2.3 billion tonnes (7%) the country is the third largest emitter after China and the United States. Nearly 70% of the total CO_2 emission is attributed because of coal combustion (International Energy Agency 2021). As per the Ministry of Coal (MoC, 2020), India's overall coal consumption was reported at 955.307 million tonnes (MT) for 2019–20. Further 70% of the coal was used for power generation, while 30% found application in non-thermal application, including steel production.

Although over the years several treaties and agreements have tried to assert a stopgap on the consumption of coal and other fossil fuel-based resources, large-scale consensus has always been on the aspect of transition. How well can existing governance composition enable the transition for people and societies alike away from fossil fuel-based path-dependent structures, towards more efficient forms of energy supply. This is essentially where the principle of just transition comes into play. Its notion is rooted in the principles of 'environmental justice', wherein the transition from a fossil fuel-based infrastructure to a sustainable infrastructure must be just and equitable for everyone that partakes in the transaction. This includes miners, communities, land, and resources.

While a transition towards sustainable forms of energy is the need of the hour, there is, however, a growing concern related to labour displacement in the existing coal value chains. Their seamless transition from a skill aspect, moving from a fossil fuel sector to a sustainable development sector in many ways will define the future of India's energy movement. Thus, there is a need for the creation of a mechanism that can help in the identification of all the possible conflicts and a pathway, which will lead to an acceptable outcome for all the key stakeholders. This paper tries to explain the notion of just transition within the Indian context and builds a framework that can help us achieve the transition.

Keywords: Doughnut Economics, Just Transition, SDG, Coal, Justice

Review of Literature

Previous scholarly attempts on just transition have focused on several facets of environmental justice, social and environmental relations, and how the overall employment trend changes in the hindsight of a coal phase-out. Evans and Phelan (2016) argue that campaigns focusing on a coal phase-out can be strengthened by engaging with just transition discourses that are typically associated with organized labour. Similarly, Stevis and Felli (2015) put forth the argument that labour unions can play an exceedingly important role in the move towards environmental justice and just transition. Additionally, McCauley and Heffron (2018) energy and environmental justice scholarships. It was originally coined as a term that was designed to link the promotion of clean technology with the assurance of green jobs. The Paris climate change agreement marks a global acceptance that a more rapid transition is needed to avert disastrous consequences. In response, climate, energy and environmental justice scholarships must unite in assessing where injustices will emerge and how they should be tackled. Just transition offers a new space for developing an interdisciplinary transition sensitive approach to exploring and promoting (1 explore the proposition of how labour unions can help reimpose the phenomenon of restorative justice, and assist organizations and corporations alike towards adopting measures that support the notion of environmentalism. Just transition scholarly work from a traditional climate justice standpoint is looked at as critical policy move that can help fossil fuel-based reliant nations mitigate their carbon footprint and tackle the implications of climate change (Baptiste and Rhiney 2016; Kortetmäki 2016; Skillington 2017). Climate justice literature, on the other hand, deals with transition from a global standpoint and how its importance is strategically linked with mitigating the rapid effect of climate change (Kortetmäki 2016; Robinson and Shine 2018; Routledge, Cumbers, and Derickson 2018).

Further, several energy scholars in their quest to devise just transition strategies from an energy justice standpoint, have focused on consumption and production patterns and suggest a move towards low carbon energy sources without compromising the overall individual well-being (Heffron, McCauley and Sovacool 2015; Healy and Barry 2017a; Lappe-Osthege and Andreas 2017) from extraction to final use, to offer an analytically richer and more accurate picture of the (in. While attempts to expand the need for just transition, the vulnerabilities associated with it and its importance within the Indian context have been made (Spencer *et al.*, 2018; Bhattacharjya *et al.*, 2021b, 2021a). There still does not exist a comprehensive framework that addresses the issue at hand. In this paper while expanding on the conceptual understanding of energy democracy, and the drivers that will seamlessly enable a move towards a just transition, an attempt has been undertaken to postulate a framework for India.

The Case for Energy Democracy

The accelerated phenomenon of climate change over the last few decades has forced the hand of several governments across the world to deploy strategic action moves to tackle its growing impact. While the acceptance of climate change-based policy moves within the overall policy discourse has been lauded, it has, however, lacked the conception of due diligence and social cohesion. This notion has largely been relevant within the gambit of land acquisition and population rehabilitation. Consider the example of the Narmada Water Dam project whose population rehabilitation issue has sparked an extensive debate amongst activists and social pioneers for decades. Still, as many as 500,000 people in the three states of Maharashtra, Gujarat, and Madhya Pradesh have been displaced, more than 50% of them being adivasis or the indigenous people (Kavish 2020). Their lands, livelihoods, and cultures now stand submerged in the dam waters, and they still await proper resettlement and rehabilitation, three decades on. As per a Lok Sabha Reference Note, 2013, over the last 50 years around 3300 dams had been constructed in the country and most of them had led to large-scale forced eviction of vulnerable groups. It added that the situation of the tribal people was of special concern as they constituted 40% to 50% of the displaced population (Sabha 2013).

While, for years, water dams were touted as the beacon of water conservation and energy creator, they have, however, failed on the aspect of societal upliftment and on the spectrum of energy democracy. The lack of focus of such environmental policy measures that have severe unintended consequences has exasperated the movement towards democratically sanctioned energy production, which has critical linkages to societal upliftment and social capital maintenance. Although there is no universally accepted definition of energy democracy, its roots can be traced to the conceptual understanding of the participatory democracy process. Similarly, what most scholars do agree upon is that the phenomenon is largely about workers and communities who must have the ability to decide who owns and operates our energy systems, how energy is produced, and for what purpose (Sweeney, Benton-Connell and Skinner 2015).

What just transition actually aims for is the establishment of a societal network whose principles are immersed within the framework of energy democracy. It shifts energy monopolies to 'energy democracy': community-owned and controlled renewable energy that is treated as a public 'commons' (Fairchild 2017). This process thus allows for an increased level of governance participation and makes room for innovation to take place. Scholarly work is riddled with examples of how participatory democratic processes have succeeded in establishing cohesive community relations and increased participation in governance proceedings. By 1997, the fabled participatory budgeting experiment that started in 1989 in Porto Alegre had helped improve sewer and water connections, and educational and health infrastructure. However, most importantly, the experiment gave people a voice, and improved participation in budgeting meetings from 1000 people per year in 1990 to about 40,000 in 1999 (Gelman and Votto 2018).

Additionally, vying for a transition away from fossil fuels and bringing in participatory democratic functional systems not only embodies the skeleton of 'climate justice', but also 'economic justice'. A just economic system will be poised to move away from the aspect of rentier economy which seldom plagues fossil fuel-rich economies, and largely stunts their economic growth (Brahmbhatt, Canuto and Vostroknutova 2010).

In their quest to uphold the principles of deliberative justice, several countries have begun involving their citizens within deliberations on environmental justice, sustainability, and climate change. In France, following the Yellow Vest movement, a citizen assembly on climate change was implemented in 2019 at the national level. Similar practices were then adopted by the United Kingdom and Scotland. In Germany, the federal parliament supported the first national citizen's assemblies that focused on the future of democracy and governance role in the global context. Civil society groups demanded a focus on sustainability. In May 2021 a citizen assembly (Bürgerrat) on sustainability was initiated by different civil society groups. At the local level, citizens' assemblies mostly focused on areas of town planning and developed often detailed reports for the city council (Kersting 2021).

Just Transition in the Indian Context

India's coal-based thermal power sector is one of the country's biggest emitters of carbon dioxide (CO_2). It spills out 1.1 gigatonne of CO_2 every year; this is 2.5% of global GHG emissions, one-third of India's GHG emissions, and around 50% of India's fuel-related CO_2 emissions (DTE 2020). A transition away from fossil fuels is an environmental need of the hour in order to mitigate any predicted trickle-down impact that it can potentially cause.

Apart from the socio-economic vulnerabilities that can plague a state in the case of phase out of fossil fuels such as loss of social capital, loss of access to resources and unemployment, one of the elemental issues that keeps states away from restructuring their economy is the existent financial interlinkages between the state and the fossil fuel. According to political scientist Michael Ross 'rentier effects may occur if the government earns direct and considerable revenues from resource extraction' (Ross 2001). Coal royalties are a major source of revenue for rentier economies like coal states in India; as per latest available statistics, royalty paid from coal mining in India has increased from Rs 99.73 billion in 2014/15 to Rs 147.46 billion in 2018/19 with a CAGR of 8.14%. Royalty received from coal mines in Chhattisgarh, Madhya Pradesh, Odisha, and Telangana are around 15% each in total coal royalty collected in the country. States such as Maharashtra and Uttar Pradesh accounted for almost 8% and 3% of the total coal royalty in India, respectively (Bhattacharjya *et al.*, 2021a).

Weak governance measures and institutional structures in resource curse hit states, breed inequality amongst the population, this is a representative fact in India. An alarming percentage of population within India's coal mining states reside in the lowest two wealth quintiles. While the national average for the same stands at 40%, all the coal mining states exceed this limit; Chhattisgarh – 59%, West Bengal – 53%, Odisha – 63.8%, Jharkhand – 68%, Madhya Pradesh – 54.7% (NITI Aayog 2021). The Energy and Resources Institute (TERI) undertook a perception survey in 2011 within the coal mining states of West Bengal and Jharkhand to understand the social impact of coal mining and the effectiveness of the policies. The survey brought out three main governance challenges that need to be addressed. First is the inadequate capacity of regulatory bodies, which results in ineffective monitoring and regulation. Second is the lag in compensation and absence of holistic measure to restore income levels of displaced communities, and is the ineffectiveness in addressing environmental challenges that are causing various problems to the communities (Khanna 2013).

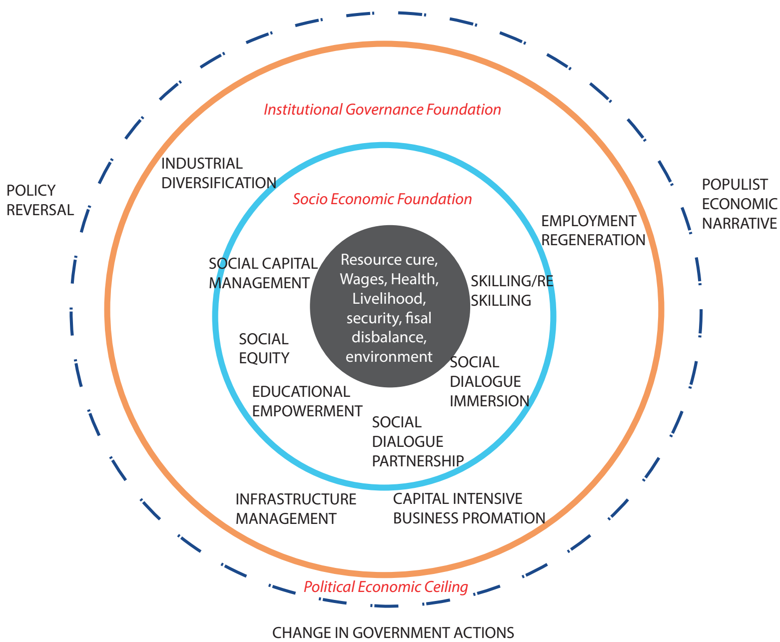

FIGURE 1: Double Doughnut Just Transition Framework

While there are potentially many issues that need to be addressed in order to fulfill the principles of just transition in India, but before that happens, it is important to understand how deeply entrenched the interdependencies between the fiscal system and the coal extraction are, and how the institutions have enabled the emergence of a system that has defied the principles of welfare economics.

Just Transition Framework

The essential principles that govern any aspect of a framework lie in its interconnected nature, how different elements interact with each other, and its diversity. These principles in all fairness are the guiding fundamental factors that largely makeup the double doughnut just transition framework. The doughnut-based framework development technique was first pioneered by University of Cambridge economist Kate Raworth, who critiqued mainstream economics and its inability to include ecological and societal parameters within the overall economic analysis system (Raworth 2017). Similar belief exists here as well, as the framework developed for this paper is inspired from Ms Raworths work, but with its own exceptions.

To put it radically, the doughnut framework is a compass that points towards the steps that must go into future just transition processes in India. Upon carefully analysing the framework we see, its clear division into two parts (hence the double doughnut), socio-economic and institutional governance foundation. While the purpose of this division is to help people understand the elements that govern these fundamentals, the nature of the framework and the elements in it are extremely interdependent and volatile, given the degree of linkages that exist between them. It may sometimes seem like a viable alternative to seek to design policies that addresses each of the socio-economic and institutional boundaries individually; but that simply will not work. For instance, researchers have found that job creation is a poor proxy for a just transition. The kind of jobs, how secure they are, how long they last, and related forms of community resilience and innovation in the face of dynamic energy markets are much more meaningful (Healy and Barry 2017b)from extraction to final use, to offer an analytically richer and more accurate picture of the (in. The interconnected nature of all the elements demand that they each be understood as part of a complex socio-economic system, and, hence, be addressed as a greater whole.

Structure

Below the doughnuts socio-economic foundation lies a bottomless pit that essentially is the representation of what can happen if the just transition process in line with the respective fundamental elements is not undertaken. In the absence of measures that address the socio-economic and institutional mechanisms we will continue to witness the existence of a resource curse plagued economy that exerts a significant amount of pressure on the fiscal balance, stagnates wages, depletes livelihood resources, and a degrades the ecology and environment.

Beyond the gaping hole lies the first part of the doughnut, socio-economic foundation. This area of the crust is responsible for securing the basic necessities for individuals and societies alike, which are pivotal for maintaining a socially just society where equitable distribution of resources can take place in a post-coal phase-out scenario. Resource-dependent communities are subject to both unstable socio-economic patterns and negative environmental externalities associated with resource extraction. Research has long illustrated how the unstable nature of extractive industries impact community-level outcomes through booms and busts (Winkler, Cheng and Golding 2012). Tools such as educational empowerment, skilling/re-skilling, labour union immersion, social capital management, social dialogue partnership, and building social equity can help societies emerge out of the economic constraints that the existing institutions instill upon them.

Albeit the first structure expanded on the notion of building distributive efficiency within a society, the second layer of the doughnut lays the effective groundwork for governance and institutional reactivity, and the tasks they ought to undertake to ensure the successful implementation of just transition projects.

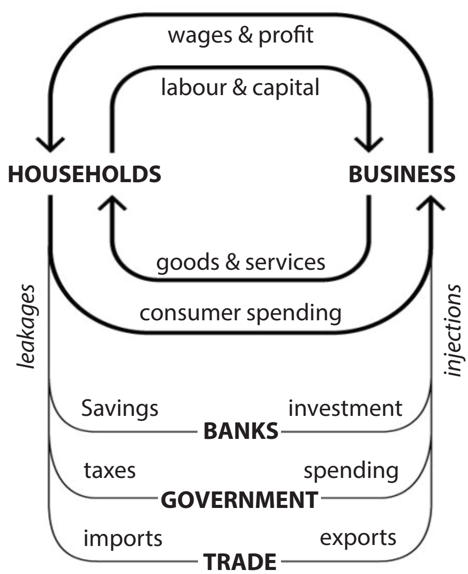

FIGURE 2: Circular flow diagrammatic representation (Samuelson, 1948)

The idea of a circular flow of economy was first posited by Richard Cantillion in the 18th century and was then subsequently developed by the likes of Quesnay, Marx, Keynes, and many other economists (CFI 2021). The circular flow pictures the economy into two groups — households and firms — that interact in two markets: the goods and services market in which firms sell and households buy and the labour market in which households sell labour to business firms or other employees. However, several critiques of the model have emerged over the years and that its implementation has not aged well, given it focuses only on the monetary flow and does not account for the issues that the world is battling today, especially in the form of climate change and sustainability. Economists Jonathan M. Harris and Anne-Marie Codur explained that although labour and manufactured capital are regenerated through the circular flow model and that the provision of food and other necessities makes more labour possible, and investment builds up manufactured capital over time, but what about the very first factor of production, energy? Natural resources? (Harris and Codur 2004), Resource curse-hit states do not account for this factor of production within their economic formula, which, thus, ruins the ecology, fiscal balance, and the economy at large.

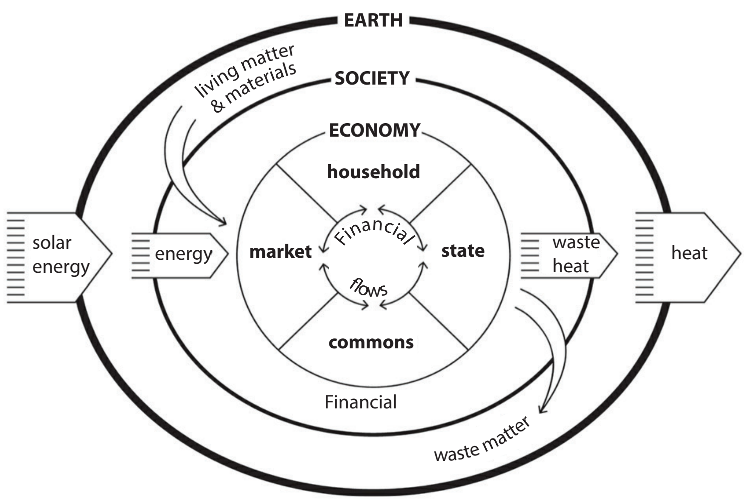

FIGURE 3: Kate Raworth's improved representation of how a circular economy should be (Raworth, 2017)

The function of governance institutions is to tackle this market failure, improve the overall social welfare factor, and bring in the conception of sustainability within the overall policy discourse. The second layer of the doughnut is designed to incorporate progressive economic measures that compliment the new era of growth for a just transition society.

Elements like industrial diversification can help the state move away from their primary source of income, and build capital-intensive industries such as manufacturing and renewable energy on the coal mining lands. This move will help in large-scale employment generation and bring the workers within the formal work force, given that illegal mining is rampant in India's coal states (Lahiri-dutt 2007). Research has found that manufacturing industry in India has a positive multiplier effect when it comes to job creation, as it creates two to three indirect jobs in related activities (IBEF 2012). The Indian solar sector is expected to create over 300,000 jobs by 2022, to meet this target the number of manpower required by ground-mounted solar rooftop solar projects would need to increase significantly (India Today 2020). Rooftop solar in India produces 24.72 jobs per year per MW, while ground-mounted solar produces 3.45 jobs per year per MW (Kuldeep et al. 2017). Further, 120,990 direct and indirect employment jobs were created within the solar sector in 2017 (Tyagi 2017). Further, an augmented level of industrial diversification and enterprise setup will encourage private investors to come in and further result in progressive technological prospects to take shape.

The final element of the foundation, infrastructure management, makes for an integral part in the entire governance proceeding. Coal companies in India invest a considerable amount of money in their CSR (Corporate Social Responsibility) activities, aimed at socially reforming the local area. Between FY 17 – FY 20, Coal India, and its subsidiaries, spent Rs 1978 crore on CSR, primarily on building infrastructure within the health and educational domains (The Economic Times 2020). In the case of a coal phase-out, the money needed to manage these critical establishments will also go away with the coal companies. In such a situation, the institutions need to step up and assume its functioning, the grants to local bodies which are offered by the finance commission can become an effective alleyway to help maintain and thrive these establishments, which over the years become an essential part of the local social capital.

Although the tangible parts of the framework have been explained, an intangible aspect does exist that holds the entire structure together, and that is the political economic ceiling. The idea of just transition is extremely political in nature, not only from a technological aspect, but from power, financial, and resource distribution perspective as well. Economies that are culturally embedded around the functioning of a natural resource have a social identity attached to it. It is just not a source of income, but a way of life, which, in hindsight, defines people and who they are. In order to nudge economies out of this cycle, the balance between distributive and economic justice alongside political economic state of orders will have to be maintained. That can only be established if our primitive thinking of equating progress with GDP growth is substituted with the idea of 'just' and 'fair'. In his seminal work *Theory of Justice*, political philosopher John Rawls expressed the importance of equal basic rights and liberties and that they must not be traded off against other social goods (Rawls 1971). In the absence of principles that do not uphold the phenomenon of economic, distributive and ecological justice, we will see governments penetrate the glass ceiling of political economy within the framework, which will further give rise to populist and neoliberal economic narratives, policies that do not support environmental sustainability and continual change in government actions, that negatively impact the energy transition process.

Conclusion

Brunnschweiler and Bulte in 2008 presented their views on the phenomenon of resource curse, stating that it is the abundance of natural resources that worsens the quality of institutions and governance, and not the other way around. They show that resource indicator, ratio of natural resource exports to GDP is positively associated with governance measures such as rule of law and government effectiveness. What does this tell us?

While in this paper we have elaborated on the framework for just transition and its importance in India, there is a need for an institutional measure that can infuse everything together. A polycentric governance system approach may very well be the solution the nation needs. While collective action is at the heart of its functionality, the system also promotes social dialogue partnership by improving social connectivity whilst also enabling broader levels of participation, improving potential for response diversity, and building redundancy that can minimize and correct errors in governance. From an environmental standpoint, polycentric governance system has been successful in watershed management groups in South Africa and the management of large-scale irrigation systems in the Philippines where the system has facilitated participation by a broad range of actors and incorporation of local, traditional, and scientific knowledge (GRAID 2021).

For the double doughnut framework to be successful in its quest for achieving a just transition scenario, there is need to not only adopt methods of economic analysis that pay attention to the growth indicators and focus on environmental and economic justice, but also the adoption of a governance system that can effectively execute the elements governing the framework.

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CHAPTER 8

Cross-border Energy Trade in BIMSTEC Region: Opportunities and Challenges

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In a world marked by unprecedented increase in energy demand and limited availability of conventional sources of energy, no idea of national security and economic growth can be thought independently of energy security (Basu Ray Chaudhury,2009). With 22% of the global population and a significant share of people in BIMSTEC (Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation) nations without access to electricity, the objective of energy security is a priority among the BIMSTEC as well. Rapid economic growth, industrialization and increased demand for goods and services has led to a rising trend in primary energy consumption per capita in all BIMSTEC member countries, namely Bangladesh, Bhutan, India, Nepal, Sri Lanka, Thailand, and Myanmar. This trend is likely to continue till 2030 (CRISIL 2018; IEA 2019). Furthermore, to sustain their economic growth, the BIMSTEC countries require a competitive and affordable supply of energy on a long-term basis. The share of energy imports in the total energy supply suggests that most of the BIMSTEC countries are dependent upon imports to meet their primary energy needs: India (41.5% in 2018), Bangladesh (16.8% in 2014), Nepal (16.7% in 2014), Sri Lanka (57.5% in 2017), and Thailand (64% during December 2018–19) Batra, Agarwal, Panda, *et al*. 2020). However, despite being dependent upon external sources for energy requirements, the BIMSTEC region itself is endowed with abundant natural resources.

This energy potential is largely concentrated in Nepal, Bhutan, north-eastern states of India, Bangladesh and Myanmar. In addition to geographic proximity and common land borders, the potential of cross-border energy trade within this region is further enhanced by the seasonal variation in power supply and resource complementarities between India–Nepal and India–Bhutan; potential for development of sustainable hydropower plants in Nepal, Bhutan and the North-eastern states of India; and access to a wider range of energy sources such as hydropower, coal, and natural gas from these countries. However, despite several complementarities and the technical and economic feasibility of energy trade, issues of 'resource nationalism' act as impediments in the process of bilateral and multilateral cooperation in the region.

Against this backdrop, the chapter examines the forces of political economy within BIMSTEC that can be leveraged to enhance sub-regional energy cooperation. While focusing on conventional energy only, the study has a three-fold objective: first, it seeks to evaluate the existing situation of energy consumption, production, generation of the member states of BIMSTEC on the one hand while assessing existing cross-border energy cooperation among them, on the other hand. Second, the study attempts to analyse how and to what extent the formation and operationalization of the 'BIMSTEC Grid Interconnection'[40] can

[40] BIMSTEC Grid Interconnection aims to expand energy trade among member states and accelerate development of new hydro-power projects, interconnection of electricity and natural gas grids, implementation of viable renewable energy projects, and sharing of experiences, knowledge and information on energy efficiency programs (BIMSTEC 2018).

lead to an increase in utilization of the power generation capabilities. In this regard the paper also tries to focus on the BBIN countries (Bangladesh–Bhutan–India–Nepal) as a potential hub for cross-border energy cooperation, which may have spill over effect on the Bay of Bengal region. The study examines the impediments, if any, in achieving functional cross-border energy cooperation in the BBIN region. Finally, it also analyses geo-political factors associated with energy imports from outside the BIMSTEC region keeping the changing dynamics of international milieu in mind. Hence, based on an analytical method, the study focuses on opportunities and challenges of cross-border energy trade in BIMSTEC in furthering the agenda of sustainable development.

BIMSTEC at a Glance: Energy Consumption, Production, Generation Capacity, and External Dependence

The energy sector plays a very important role in economic development and evidence shows that the expanding electricity sector contributes to economic growth in many countries (Gunatilake, Wijayatunga, and Roland-Holst 2020). Rapid industrialization and urbanization have increased the demand for energy resources. With access to energy playing an important role in socio-economic development and human well-being, especially in less developed and developing countries, energy security has become a priority in every country across the world. The BIMSTEC countries are no exception to it as these countries still lack basic access to electricity and energy for cooking (World Bank 2020b). With rising economic aspirations and increasing population, BIMSTEC countries will be among the key players responsible for the rapid increase in energy demand across the world. India, an important player in the sub-regional grouping, has already established itself, along with China, as one of the leading agents in the global increase in energy demand (BP 2020).

Most BIMSTEC countries have made significant improvements in ensuring access to electricity since the dawn of the 21st century.[41] Figure 1 highlights the basic interlinkage between energy and economic growth. Despite the link between growth in GDP per

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41 Though in 2000, the share of population with access to electricity in India was much higher than that in Bhutan, after 17 years, Bhutan has been more successful than India in ensuring almost universal access to electricity for its citizens. Per capita GDP and access to electricity both doubled over the time period 2000-17 in Bangladesh. Thailand had the highest GDP per capita and share of its population with access to electricity in 2000, among the BIMSTEC nations. By 2016, Thailand has been successful in achieving universal access to electricity and it's GDP per capita is still the highest. Although GDP per capita grew by only 49 percent from $1540 in 2000 to $2298 in 2016 in Nepal, the share of population with access increased from a mere 27 percent to 90 percent between 2000 and 2016, respectively. Nepal still has the lowest per capita GDP in the region. In Figure 1, the scatter distribution depicts the positive correlation between access to electricity and GDP per capita.

capita and improvement in access to electricity, the per capita electricity consumption in the BIMSTEC countries is still abysmally low (Figure 2). Except for Bhutan, the per capita electricity consumption of all the other BIMSTEC countries was well below the world average of 3501 kWh/capita in 2019 (BP 2020).[42]

The BIMSTEC countries, therefore, must tap into the resources available within the region to not only increase the share of population with access to electricity but also ensure energy security.

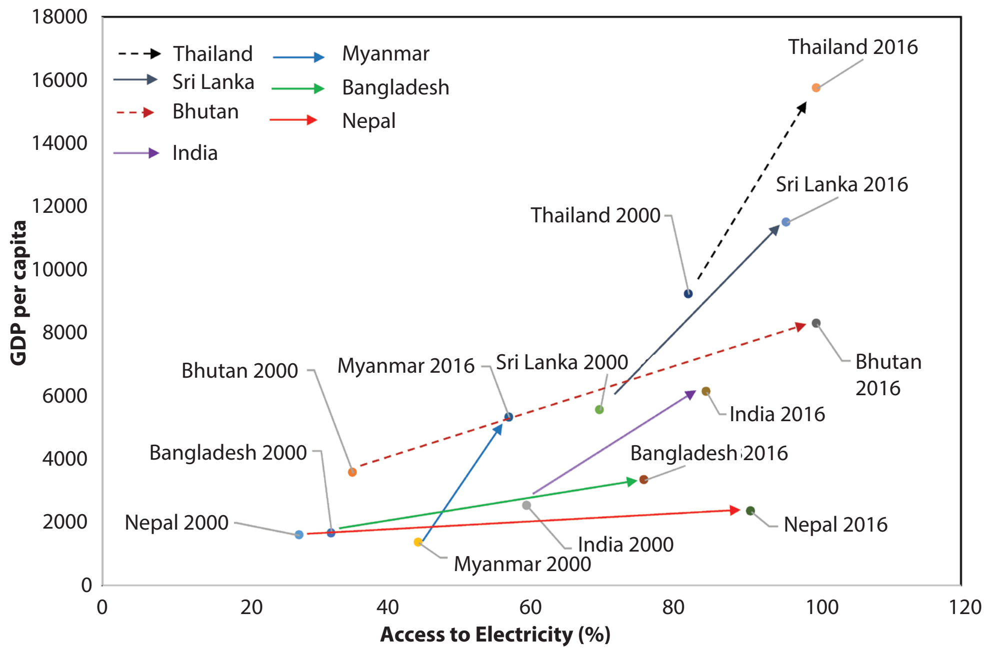

FIGURE 1: GDP per capita versus share of population with access to electricity (2000–16)

Source: Authors' calculation using data from World Bank

42 Although per capita electricity demand increased from 69 kWh/capita in 2000 to 177 kWh/capita in 2019, Nepal has an abysmally low level of per capita electricity consumption. It is estimated to be one-twentieth of the global average (Gunatilake, Wijayatunga, andRoland-Holst 2020). In contrast Bhutan hadper capita electricity consumption of more than 9000 kWh in 2019 while Myanmar (442 kWh/capita), Bangladesh (550 kWh/capita), Sri Lanka (759 kWh/capita) and India (1141 kWh/capita) still have very low per capita electricity consumption figures.To put things in perspective, the difference in per capita electricity consumption among the BIMSTEC countries and that of major global economies like United States (13375 kWh/capita), Australia (10519 kWh/capita), France (8835 kWh/capita) and United Kingdom (4794 kWh/capita) is also stark (BP, 2020).

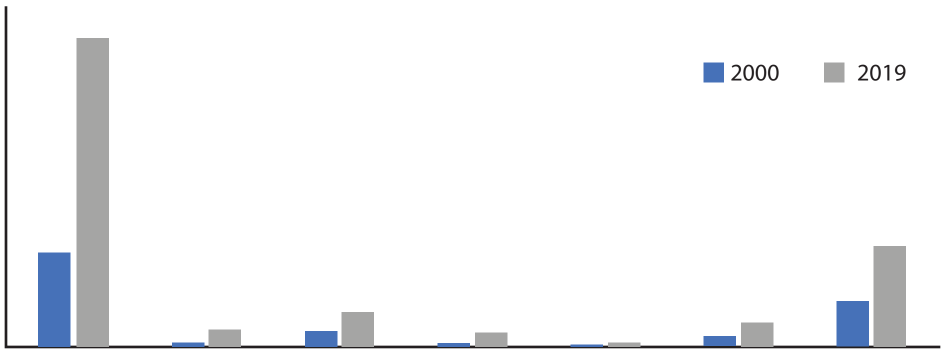

FIGURE 2: Per capita electricity consumption (kWh/capita)

Source: Our World in Data based on BP Statistical Review of World Energy and Shift Data Portal

» Energy demand and supply scenario in BIMSTEC

Based on estimates of total primary energy[43] supply and consumption obtained from the BIMSTEC Energy Outlook 2030, the total primary energy supply in BIMSTEC region in 2008 was 772 million tonnes of oil equivalent (Mtoe) (IRADe-SARI/EI, 2017). It is estimated to increase to 1758 Mtoe in 2030. During the same period, the total primary energy consumption was 539 Mtoe in 2008 and is estimated to increase to 1210 Mtoe in 2030 (IRADe-SARI/EI 2017). Over the period of the outlook, coal continued to remain the primary source of energy supply. Although the share of oil in total primary energy consumption is expected to decline from 31% in 2008 to 29% in 2030, it nonetheless accounts for the largest share of primary energy consumption in the BIMSTEC region. Consumption of oil and oil products is closely followed by an increase in the consumption of electricity over the outlook from 13% in 2008 to 20% in 2030 (IRADe-SARI/EI 2017).

As depicted in Figure 3 and as reflected in the positive supply–demand gap for the resources, the region is well endowed with coal and natural gas reserves. However, the supply–demand for electricity is negative and the gap is expected to grow over the period 2008–30. The supply–demand gap for oil resources is expected to improve in 2030, from a deficit in 2015 to a marginal surplus in 2030. Indeed, a significant share of fossil fuel supply is obtained from imports. According to the World Bank estimates, majority

[43] Primary energy supply is defined as energy production, plus imports, minus energy exports, international bunkers and taking account of changes in stocks. These projections have been obtained from the BIMSTEC Energy Outlook 2030.

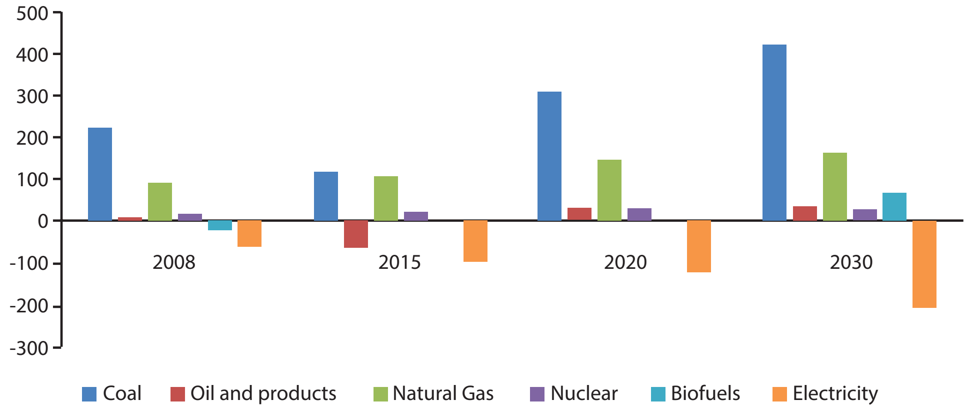

FIGURE 3: Primary supply–demand gap in the BIMSTEC region (in Mtoe)

Source: Authors' calculation based on data from BIMSTEC Energy Outlook 2030

of BIMSTEC nations are heavily dependent upon fossil fuel imports for their energy and transportation needs (World Bank 2020). The share of energy imports in the total energy supply suggests that most of the BIMSTEC countries are dependent upon imports to meet their primary energy needs[44]. Nonetheless, the overall energy profile in the BIMSTEC region suggests that coal and natural gas will remain important sources of energy. At the same time, the share of electricity in primary energy consumption will also increase, but supply will remain inadequate. Increasing cross-border trade in electricity will, therefore, be an integral component of an integrated strategy aimed towards ensuring energy security in the region.

Resource Potential among BIMSTEC Countries

Keeping this energy supply–demand scenario in consideration, it is imperative to understand the resource potential of BIMSTEC countries. The BIMSTEC region is endowed with abundant natural resources comprising 324 billion tonnes of coal, 664 million tonnes of oil, 99 trillion cubic feet of natural gas, 11 billion tonnes of biomass, 328 GW of large hydropower, and renewable energy potential of more than 1000 GW (Table 1).

[44] Energy import dependency of BIMSTEC countries is depicted in Figure 6 and Table 2.

TABLE 1: Energy resource potential among BIMSTEC countries

Resource	Coal (million tonnes)	Oil (million barrels)	Gas Reserves (TCF)	Bio-mass (MT)	Hydro Potential (GW)
Bangladesh	3,300	12	8	^	^
Bhutan	2	-	-	27	30
India	60,600	5,749	53	139	150
Myanmar	466	459	17	38	108
Nepal	-	-	-	27	83
Sri Lanka	-	150	-	12	2
Thailand	1,239	405	8	-	17
BIMSTEC Total	**65,607**	**6,775**	**86**	**243**	**390**

^ *Either resource is nil or value is less than 0.5.*

Source: BIMSTEC Energy Outlook 2030

Bhutan is endowed with large hydropower potential of 23.8 GW, although only a small fraction of it is being utilized. The hydropower sector in Nepal is also experiencing a similar trend of capacity underutilization. Nepal has a theoretical potential of 83 GW but only 43 GW of it is technically and economically feasible (Village 2014). India is the largest country in the region and has substantial deposits of coal (roughly 12% of the world's total) and huge hydro potential of 145 GW (IRADe-SARI/EI, 2017). India is also endowed with natural gas and oil. Most of the oil reserves are concentrated along western offshore and north eastern state of Assam. However, natural gas is predominantly located in the eastern part of the country. Bangladesh is well endowed with natural gas reserves of approximately 8 trillion cubic feet. Natural gas also accounts for around 70% of the country's primary energy mix. Driven by increased demand, these reserves have been rapidly declining. The problem is further accentuated by lack of discovery of new gas fields in the country. The country has very limited hydro potential due to relatively flat topography. The Karnafuli hydropower station with a capacity of 230 MW is the only major hydropower station in Bangladesh (IRADe-SARI/EI 2017, 37).

Despite the diversity of energy endowments in the region, primary energy mix among the BIMSTEC countries is still dominated by coal, hydro, oil and natural gas, except in Nepal and Bhutan (Batra, Agarwal, Panda, *et al*. 2020). The energy sector in Nepal is still dominated by traditional fuel like biomass. The share of renewable energy in primary energy consumption, albeit rising, is still marginal among BIMSTEC countries (Figure 4).[45]

45 As Table 1 points out, an immense scope of utilizing more than 1000 GW of renewable energy potential exists for the countries in the region.

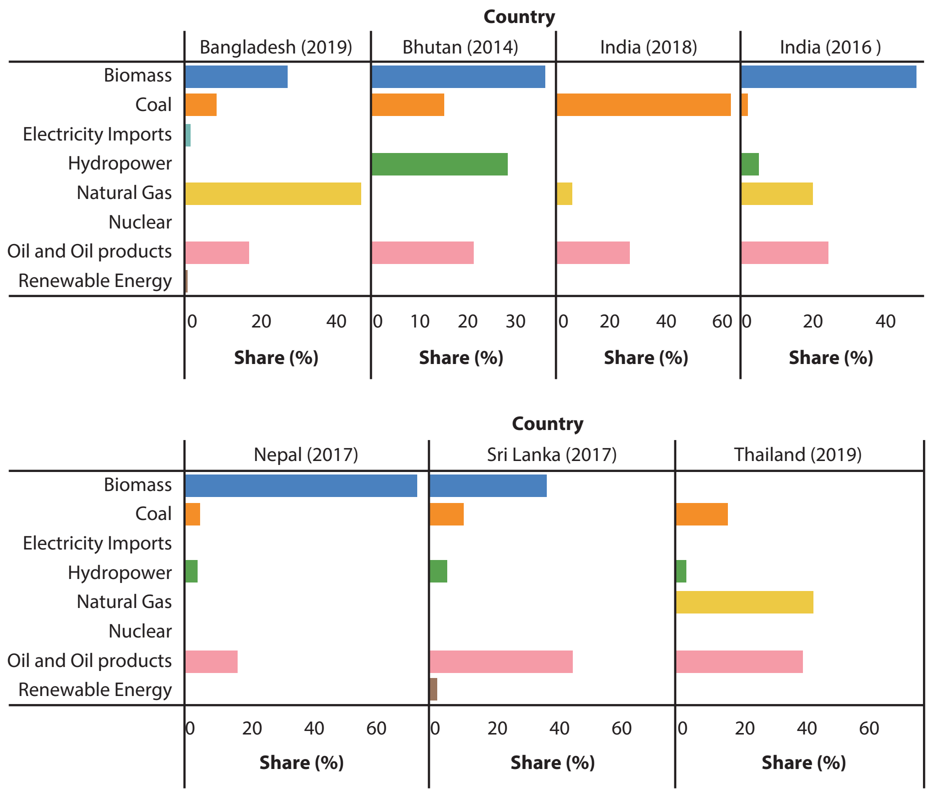

FIGURE 4: Primary Energy Mix-BIMSTEC countries

Source: Based on Batra, Agarwal, Panda, et al.2020

External Dependency to Meet Energy Requirements

Furthermore, the region is also dependent upon imports to meet its domestic energy requirements, especially the demand for oil. As Figure 5 depicts, most of the countries are net importers of energy.[46] Bhutan is a net exporter of energy but still engages in imports from India, especially thermal power during the winter months (Bhonsale 2020). Myanmar is also a net exporter although the share of net exports as a percentage of total energy use is gradually declining (Figure 5). This can be attributed to the increase in domestic

[46] Except Bhutan, for which comparable data was not available.

demand for energy.[47] Therefore, even Myanmar is likely to import a larger share of its total energy consumption in future. For net energy importing countries such as India, Nepal, Bangladesh, Sri Lanka and Thailand, utilizing domestic energy resources and improving energy efficiency are important strategies in ensuring energy security. For instance, 85% of India's crude oil requirement and almost 50% of natural gas requirements are imported (Financial Express 2020). Under the assumptions of growing energy consumption buttressed by economic aspirations of achieving a USD5 trillion-dollar economy, the *BP Energy Outlook 2020* posits India's energy import dependency to double by 2050 (BP 2020).

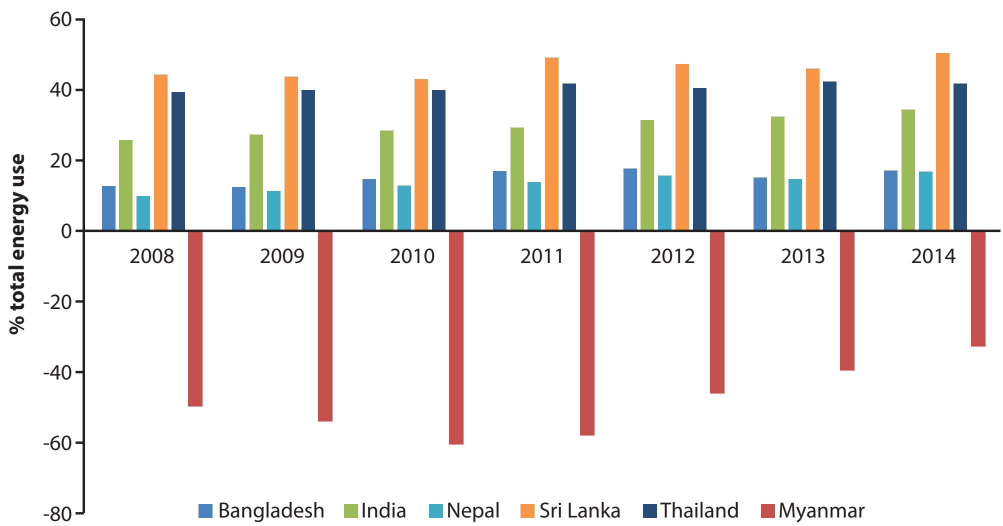

FIGURE 5: Net energy imports (% of total energy use)

Source: compiled by Authors using World Bank Data

Similarly, Thailand, which has the second highest net energy import dependency among BIMSTEC countries, is largely dependent upon imports of natural gas from Myanmar, coal and hydropower from Laos (Oxford Business Group 2017), and oil from Middle East (Asia-Pacific Economic Cooperation 2013). Nepal has very scarce coal and no known sources of oil and natural gas reserves in the country. It meets a large part of its electricity

[47] According to estimates by the Economic Research Institute for ASEAN and East Asia, final energy consumption in Myanmar increased at an average rate of 3.1% per year from 9.9 Mtoe in 2000 to 15 Mtoe in 2016. This is expected to increase further at 3% per year between 2017 and 2040 (MOEE, 2020).

requirements through imports from India.[48] This results in additional burden on Nepal's foreign exchequer while exposing the country to the political economy forces in the energy market of India that could disrupt its domestic economy. Given its vulnerability to supply shocks—border blockades in 1989 and the most recent border closure in late 2015 resulted in rationing and long queues for fuel—it is necessary that Nepal develop its hydropower sector and reduce dependency on fossil fuel imports from other countries (Asian Development Bank 2017b).[49]

Sri Lanka, which has the highest share of net energy imports in total energy use, is extremely vulnerable to geo-political forces and ranks 85 out of 128 (2019 figure) in the World Energy Council Trilemma rankings on energy security, energy equity, and environment sustainability (World Energy Council 2019).[50] Increasing imports of petroleum products from United Arab Emirates, Singapore, India, Oman, and China account for one-fifth of Sri Lankan total import bill (World Bank n.d.; Herath 2014).[51]

It is evident from Table 2 that most of the member countries of BIMSTEC are dependent on imports for their energy requirements. India and Thailand are the largest net importers, while Bhutan is a net exporter. This exposes the region to external vulnerabilities and geo-political tensions. From an energy security perspective, therefore, it is important to harness the potential within the region and explore the possibility of sub-regional cooperation.

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[48] In 2018–19, the peak electricity demand was 1320 MW as compared to total electricity generation capacity of 1182 MW. Of this, the Nepal Electricity Authority (NEA) owned 621 MW (generating 34% of total sold electricity), private investors owned 529 MW (29%) and the remaining 38% were imported from India (Gunatilake, Wijayatunga, andRoland-Holst 2020). Additionally, Nepal also imports petroleum and coal from India.

[49] This has also been termed as the 'power paradox' by scholars in Nepal. The paradox presents itself in two ways. First, despite its huge generation potential, the installed hydropower capacity is very limited and people suffer from load shedding, especially during the winter months. Second, the country is engaged in exporting hydroelectricity to India, but at the same time it is increasing its imports of fossil fuels (Shrestha, Biggs, Justice, et al. 2018).All the petroleum products consumed in Nepal are imported from the Indian Oil Corporation under a 5-year contract agreement signed on 27 April 2012. The Nepal Oil Corporation, a state-owned trading company established in 1980, imports, transports, stores, and distributes all petroleum products in the country. At present, the country's oil storage capacity is only 71,662 kiloliters, just enough for 20 days of oil product sales.

[50] Although it is not among the worst performers in terms of the Trilemma variables as other BIMSTEC countries are ranked worse:Nepal (117), Bangladesh (114), India (109), and Myanmar (104).

[51] As Sri Lanka is a small economy and, therefore, a price taker in the world energy market, international price fluctuations can affect foreign exchange reserves, interest rates, inflation, GDP (Herath, 2014) and have far reaching implications on energy access and equity in the country.

TABLE 2: Net energy imports (Mtoe)

Year	Thailand	Myanmar	India	Bangladesh	Sri Lanka	Nepal
1990	17.85	0.01	31.64	2.16	1.7	0.31
1995	32.08	0.66	53.44	3.05	2.42	0.61
2000	32.06	-2.63	91.43	3.47	3.83	1.03
2005	47.87	-7.34	121.52	4.14	4.26	1.04
2010	51.46	-8.65	204.74	4.3	4.09	1.41
2015	64.9	-9.01	306.29	7.33	5.98	1.95
2018	72.6	-4.9	347.6	8	7.6	3.8

Source: Compiled by Authors' using data from International Energy Agency.

Existing Cross-border Energy Cooperation at Bilateral Level in the Bay Region

Bilateral cooperation in the energy sector among BIMSTEC countries has been predominantly between Bhutan–India, India–Nepal, and India–Bangladesh. More recently, there have been efforts at bilateral energy cooperation between India–Sri Lanka, India–Myanmar, and Nepal–Bangladesh. Most notable among these have been the MoU between Bangladesh and Nepal on cooperation in the power sector (Panda 2019). In 2018, Nepal and Bangladesh initiated talks on electricity trade, making it one of the first multilateral initiatives which involved India, apart from Bangladesh and Nepal. However, this is yet to make any major headway (The Kathmandu Post 2018). Similarly, the Dorjilung hydropower project (1125 MW) that was jointly proposed by the Bhutan Electricity Authority, Bangladesh Power Development Board (BPDB), and Ministry of Power, Government of India in 2017 is another example of a trilateral agreement. Under the terms of the MoU signed under this agreement, Bhutan would export power produced from this project via India (Outlook India 2017).

» **India–Bhutan**

Energy cooperation between India and Bhutan has stood the test of time.[52] More recently, with an aim towards further enhancing the robust relationship between the two countries,

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52 It dates back to 1961 when the Jaldhaka agreement was signed to harness the hydropower potential of the eponymous river. This was followed by the first major hydropower project agreement between the two countries in 1974,the Chukha hydropower project (336 MW) and subsequently in 1996,Tala hydropower project (1020 MW). The CHPP over the River Wangchhustarted with a peak capacity of 336 MW. It was the first of its kind to be funded by the Indian government with a 60% grant and a 40% loan to be repaid over a period of 15 years at an interest rate of 5%. The power sold to India from the Chukha hydropower project was distributed among the states of West Bengal, Jharkhand, Odisha, Bihar, and Sikkim. Subsequently, in 1996 an agreement on the development of the 1020 MW Tala hydropower project was signed under similar financial assistance by India.

India agreed to assist Bhutan in developing its hydropower potential to 10,000 MW by 2020 in a March, 2006 agreement between the two. Development of hydropower envisaged under this agreement is still ongoing. The 1200 MW PuntsangchuI and 1020 MW Punatsanghcu II, and 720 MW Mangdechhu projects are some of the major projects in collaboration with India (Ranjan 2018). With the coming on stream of the Mangdechhu project in 2019, the jointly created capacity has crossed 2000 MW (Siddiqui 2020).

Apart from these major Run-of-the-River projects, India and Bhutan are also cooperating on reservoir projects over the Sankosh and Kuri-Gongri rivers. Sankosh and Kuri-Gongri have the capacity to generate 2500 MW and 1800 MW of electricity, respectively (Ranjan 2018).[53] Additionally, in 2014 agreements on the development of four projects under the joint venture model were signed between India and Bhutan. The four projects are Kholongchhu, Chamkarchhu-I, Wangchhu and Bunakha reservoir.[54] Under the circumstances, energy cooperation, especially hydroelectricity, is an example of a win-win situation for the two countries. On the one hand, they generate export revenue for Bhutan, while, on the other hand, they provide a source of clean and cheap reliable source of energy for India.

» **India–Nepal**

Energy cooperation between India and Nepal began as early as the 1950s with the Kosi and Gandak projects. The Kataiya power house with a capacity of 6.8 MW was built by India for Nepal on the Kosi canal during the 1950s. Subsequently, Trishuli, Devighat and Phera hydropower projects were also built with support from India. Power exchange between the two neighbouring nations began in 1971 with limited low capacity (5 MW in total) at various locations along the border.[55] The Nepal–India inter-country cross-border transmission interconnection, called the Dhalkebar (Nepal)–Muzaffarpur (Bihar, India) 400kV line project (completed in 2016), includes strengthening of the sub-national transmission network in Nepal and development of cross-border interconnection through which Nepal imports 80 MW of power from India (Ramdev 2019). Two additional lines between Kataiya (India)–Kusaha (Nepal) and Raxaul (Bihar)–Parwanipur (Nepal) were completed in 2017

[53] The Sankosh river project was expected to be completed by 2020, but progress has been delayed due to concerns over:a)the downstream impacts- especially flood inundation mapping in the 80 km reach on the Indian side till it joins the Brahmaputra; b) approval for deployment of manpower in Bhutan for conductingMEQ studies has not been rendered by Royal Government of Bhutan. Finally, the status report of the Sankosh project states that between July 2020 to August 2021 discussions at various levels of the Ministry of Power and Ministry of External Affairs, GoI, have been held to discuss the implementation module of the Sankosh HEP. The completion of the Kuri-Gongri river hydroelectric project has also been delayed.

[54] Of these, pre-construction activities of the 600 MW Kholongchhu hydroelectric project as a jointventure between Satluj Jal Vidyut Nigam (SJVN)and Druk Green Power Corporation (DGPC) will commence soon (The Hindu, 2014).

[55] Both countries share 1751 km long open border (Ministry of Home Affairs, n.d.), which has 22 cross-border power exchange facilities, most of which are through the Indian state of Bihar.

(132 kV) (Chowdhury, 2020). There are several other grid interconnections, through Uttar Pradesh and Uttarakhand, between the two countries.[56] Further, as a part of the power development agreements signed between the two countries, efforts are being made to develop immense hydropower potential of Nepal through the construction of major hydroelectric projects such as the Arun-III (900 MW), Upper Karnali (900 MW), and Pancheswar multi-purpose project, among several others (CUTS-CITEE n.d.).

In an attempt to counter grow Chinese interventions in the Nepalese energy sector and restore trust between the two nations, the first cross-border petroleum products pipeline in the region, constructed and funded by Indian Oil Corporation Ltd., connecting Motihari in India to Amlekhgunj in Nepal, was remotely inaugurated by the Prime Ministers in September 2019 (Kumar 2020).[57]

» **India–Bangladesh**

Energy cooperation between India and Bangladesh was formally initiated in November 2009 shortly after a high-level Bangladesh delegation led by Secretary, Power division, Ministry of Power, Energy and Mineral Resources. This culminated in the signing of an MoU between the two countries in January, 2010. The key features of the MoU were exchange of power through grid connectivity, joint venture investment in power generation, and capacity development of Bangladesh Power Development Board (BPDB) (Chatterjee, Chaudhury, and Basu 2015).

It led to the commissioning of a 500-MW high-voltage direct-current (HVDC) link at Bheramara (Bangladesh) with interconnection at Baharampur (West Bengal) in October 2013. As a result of grid interconnection, Bangladesh receives 470 MW out of which 250 MW is at a pre-determined price and the rest is purchased at market rates. An additional export of 100 MW of electricity from the Palatana power plant in the north-eastern state of Tripura to Comilla in Bangladesh was also commissioned in 2016 (The Economic Times 2016). A 1320 MW coal-based plant at Rampal in Khulna district of Bangladesh, a joint collaboration between the National Thermal Power Corporation of India and BPDB,

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56 The Anandnagar–Bhairwan (33kV) and Nanpara–Nepalganj (33kV) lines run between Uttar Pradesh and Nepal. Similarly, a 33 kV interconnection linking Lohia–Mahendranagar (Nepal) is in Uttarakhand. Three 11 kV lines between Pithoragadh–Baitadi, Dharchula–Jajibe and Dharchula–Piplu also exist along the Uttarakhand–Nepal border (IRADe-SARI/EI 2017).

57 The pipeline has a capacity to carry 2 million tonnes of petroleum products annually and gives Nepal access to cost-effective mode of uninterrupted fuel supply. Along with the approval of Rs 1236.13 crore investment for the transmission component of the Arun-III project by the Indian government in March 2019 to evacuate power from Nepal to India, the operationalization of the oil pipeline will provide much needed fillip to energy co-operation between the two countries.

TABLE 3: Transmission interconnections between India and Bangladesh

Interconnection Project	Type Capacity	Commissioning (Year)	Capacity (MW)
India – Bangladesh (existing)			
Baharampur – Bheramara	HVDC 500 KV	2013	540
Surjyamaninagar – North Comilla – South Comilla	HVAC	2016	
India – Bangladesh (ongoing)			
Katihar – Parbotipur/Barapukuria – Bornagar	765 KV		
India – Bangladesh (proposed)			
Rangia/Rowta – Bangladesh – Muzaffarnagar	800 KV		7,000
Bongaigaon (Assam) – Purnia (India) via Jamalpur or Barapukuria, dropping 500-1,000 MW to Bangladesh	765 KV		

Source: BIMSTEC Energy Outlook 2030

was proposed in 2017.[58] Grid interconnections such as that between Katihar-Parbotipur/Barapukuria-Bornagar are ongoing, and several others are in the pipeline. One of the major advantages of these grid connections is the possibility of sending surplus power generated in the northeastern parts of India to the eastern states through Bangladesh, instead of the existing route via the 'chicken's neck' corridor near Siliguri. In return, Bangladesh will have access to 20% of the electricity being transmitted through its territory (Bose 2018).

Another major step forward in strengthening India–Bangladesh energy cooperation is the agreement signed at Dhaka on 22 April 2015, between the Numaligarh Refinery Ltd (NRL) and the Bangladesh Petroleum Corporation, for the export of petroleum products to Bangladesh.[59]

[58] However, due to opposition from environmentalist and academics on the basis of its proximity to the Sunderbans the project has come under scrutiny (Ghosh 2018). Its ramifications for regional energy cooperation are discussed later in the chapter.

[59] Petroleum products will be exported through the proposed 130-km-long Indo-Bangla Friendship Pipeline (IBFPL) from the Siliguri depot of the Numaligarh oil refinery in India to Parbitipur in Bangladesh.Upon completion, 10 million Mtoe will be transported annually through this pipeline. It will drastically reduce time and transportation costs.

The above facts and figures clearly reveal that the contiguous zone comprising Bangladesh, Bhutan, Nepal, and the north-eastern states of India is rich in energy resources. Cooperation and integration of energy resources within this zone can create economies of scale in production and generation of electricity from various sources. This can enhance energy security in the region and in this context bilateral understanding between the member states may have spillover impact in strengthening multilateral cooperation in energy trade in the Bay region (Ferdousi and Mostaque n.d.).

BBIN as a Hub of Energy Cooperation in BIMSTEC

A feasibility study on a trans-BIMSTEC gas pipeline was the first initiative across border energy cooperation in BIMSTEC and a year later, in 2005 the first BIMSTEC Ministerial Conference on Energy was held in New Delhi, India. During this meeting the 'Plan of Action for Energy Cooperation in BIMSTEC' was formulated (Government of India 2005).[60] Ever since, BIMSTEC as a sub-regional grouping has been gainingits momentum to strengthen cross-border energy cooperation and it is evident from the signing of the MoU on BIMSTEC Grid-Interconnection by the member countries in 2018.[61]

60 Multilateral initiatives on energy cooperation in South Asia began with the forming of the SAARC Technical Committee on Energy in 2000. This was followed by the establishment of the SAARC Energy Centre in Islamabad, Pakistan in 2004.

61 A few years prior to the MoU on BIMSTEC Grid Connection, India, along with France,launched the International Solar Alliance (ISA) at the COP-21 in Paris in 2015. The ISA is a coalition of solar resource-rich countries that lie either completely or partly between the Tropic of Cancer and the Tropic of Capricorn. During the first assembly of the ISA in 2018, Indian Prime Minister Narendra Modi laid out his grand plan of 'One Sun One World One Grid' (OSOWOG). It is an initiative to build an ecosystem of interconnected renewable resources across the world. This idea stems from the fact that the sun never sets for the entire planet, and if there was a global solar energy grid, it may help solve some of the problems of energy security in a sustainable manner. Its implementation is planned in three phases. The first phase involves building connectivity within the Asian continent. In the second phase, it is to be connected with the various energy pools in Africa, and in the final phase it will be extended to connect the entire globe. Several BIMSTEC nations like Bangladesh, Sri Lanka, Myanmar and India are already members of the ISA. This initiative will definitely help in ensuring access to clean energy in these countries. But creating a solar grid across countries will require harmonization of energy policies across countries, cross-border transmission infrastructure, energy trading norms, etc. Furthermore, as observed in the case of conventional energy cooperation (discussed in a subsequent section), there are several political economy factors that have hindered progress towards multilateral energy cooperation. Initiatives like the ISA and OSOWOG will also face these problems. Moreover, renewable energy cooperation has its own dynamics and is beyond the scope of this chapter.

Indeed, energy cooperation in the BIMSTEC region has evolved through bilateral arrangements, with India being the central figure because of its geographical location and large economy. The bilateral arrangements between India–Bhutan, India–Bangladesh and India–Nepal are well established now and are being further strengthened. Under the circumstances it is evident that the BBIN sub-grouping, with its already well-established energy cooperation initiatives, is well poised to be the stepping stone for the ultimate establishment of an energy market in the Bay of Bengal region. India can play a major role in promoting energy cooperation not only due to its large economic strength, but also owing to the fact that it is centrally located in the BBIN region.

Nonetheless, any trans-border energy cooperation cannot be envisaged without major reforms in the Indian energy sector as the country is a major catalyst in this regard. Consequently, the revised guidelines issued by the Central Electricity Regulatory Commission (CERC) on cross-border energy trade (2018) within BIMSTEC are of paramount importance (Government of India 2018). Based on a survey of global experiences in cross-border energy trade, the following elements are crucial for energy trade and cooperation (Vaidya, Yadav, Rai, *et al*. 2019):

» Provision for cross-border electricity trade (CBET)

» Third-party transmission access

» Domestic power sector reforms

» Power trading protocols

» Regional institutions with supranational authority

» Cross-border transmission interconnections

The current status of BBIN countries on these key elements is affirmative on CBET provision. However, it is yet to establish third party transmission access, and there is an absence of a regional power-exchange market.[62] The BBIN sub-grouping also lacks an institution with supranational authority to harmonize policies, regulations and legislations pertaining to CBET. Table 4 provides a detailed analysis of the current status of the respective BBIN countries and the sub-grouping as a whole on these key parameters.

[62] The Indian Energy Exchange Limited (IEX) is an exception in this regard. The IEX provides a nationwide, automated trading platform for physical delivery of electricity, Renewable Energy Certificates and Energy Saving Certificates.

TABLE 4: Current status of BBIN countries on key elements of cross-border energy cooperation

	Bangladesh	Bhutan	India	Nepal	BBIN
CBET provision	Yes	Yes	Yes	Yes	Yes
Third-party transmission access	No	No	No	No	No
Power sector reforms					
Regulatory commissions	Yes	Yes	Yes	No	Mixed
Competitive bidding in hydropower	-	Yes	Yes	Yes	Yes
Restructuring	Yes	Yes	Yes	No	Mixed
Power trade protocols					
Bilateral power-purchase agreements (PPAs)	Yes	Yes	Yes	Yes	Yes
Competitive power-exchange markets	No	No	Yes	No	No
Regional institution	-	-	-	-	No
Cross-border transmission					
Interconnections	Yes	Yes	Yes	Yes	Yes
External support for infrastructure	Yes	Yes	No	Yes	Mixed

Source: Vaidya, Yadav, Rai, et al.(2019)

It is noteworthy that the revised CBET guidelines (2018) allow cross-border entities to trade in the Indian Day Ahead Markets (DAMs).[63] This is definitely a move in the correct direction for fostering sub-regional energy cooperation. India's national policy on cross-border electricity trade (CBET) assumes central importance in energy cooperation in the sub-region. The first draft of the guidelines on CBET issued by CERC in 2016 was opposed by Bhutan and Nepal on the grounds that electricity could only be exported to India by companies that were owned by the respective governments of these countries or by those having at least 51% equity investment of Indian public or private companies after obtaining a one-time approval from the designated authority (Dorji 2018). Under the amended guidelines issued in 2018, these restrictions were removed although exports (imports) were still subject to generation capacity exceeding (falling short) demand.

[63] The Day-Ahead Energy Market (day-ahead market) is a financial market where market participants purchase and sell electricity at financially binding day-ahead prices for the following day.

Overall, the BBIN countries have several technical requirements in place. Harnessing the potential of the existing energy transmission infrastructure in the BBIN countries can catalyse the process of establishing the BIMSTEC Grid Interconnection (see Map 1). Techno-economic rationale for sub-regional energy cooperation through cross-border electricity trade is founded upon the benefits of lower power costs, demand diversity, and complementarity (Mediratta 2016).[64] Regional energy markets also improve competition by reducing market.

MAP 1: Cross border sub-regional energy trade possibility

Source: Hossain (2019)

64 A caveat is in place here. CBET based on market instruments ensure that power trading protocols are uniform and consistent for all the players.But in the presence of politicaleconomy factors like crony capitalism, and technical factors like lack of harmonisation of policies, it leads to market failures.The uniformity and consistency in trade protocols will be absent. Moreover, there will be information asymmetry among the players with the rich players (in the context of international energy cooperation it refers to the more powerful nation) enjoying an undue advantage over the other. These challenges must be addressed and when a level playing field is established, only then can the markets function efficiently to promote smooth trade in energy.

Concentration (Mediratta 2016).[65] The benefits from CBET are also contingent upon the harmonization of grid codes, communication and information systems, operational parameters, and connectivity standards for grid participants (Asian Development Bank 2017a). In this regard the multilateral development banks and donor agencies have aimed at synchronizing the technical, regulatory, and bureaucratic affairs associated with energy cooperation among BBIN countries. The role of the Asian Development Bank (ADB), United States Agency for International Development (USAID) and the Japan International Cooperation Agency (JICA) may be cited as example.

However, the social, political, and economic history of the countries in the sub-grouping creates unique political economy dynamics of energy cooperation. Along with the technical feasibility of energy cooperation, the political ramifications and conditions must also be favourable. Otherwise, the overall energy cooperation within the sub-region will remain underutilized. Due to some of these factors, the pace of development of cross-border energy trade in the BBIN sub-region is still sluggish despite lot of potentialities.

Major hiccups

Three decades of national and regional efforts have failed to develop a single multilateral energy project (Huda 2020). Against this background, it is imperative to understand the major factors that have hindered progress along this path so far. Four major challenges that need attention to understand the dynamic inter-country relationships in the BBIN sub-region are: regional geo-politics, lack of political will from the leaders, security challenges, and environmental concerns.

» **Bilateralism in changing regional milieu**

A major impediment to multilateral energy cooperation has been India's fragmented approach to regional cooperation. India as a major power in this region has preferredbilateralism over multilateralism.[66] More so, historical legacy has vitiated the regional atmosphere with mutual mistrust and suspicion in a way that policies of

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65 For example, in the BBIN sub-region, India has a day-ahead market run by two power exchanges:the IEX and the Power Exchange of India Limited. It is transacting around 4000 MW (or 100 million kWhs or MUs) daily. Integration of the 150 GW Indian system with that of Nepal (1.5 GW), Bhutan (0.5 GW) and Bangladesh (10 GW), market integration can reduce the share of market concentration enjoyed by the Indian system. Reduction in market concentration is an indicator of increased competition. In this manner, integration of the power systems of Bhutan, Nepal, and Bangladesh can boost competition in power trading in the sub-region.

66 In fact, the SAARC summits are evident of such strategy. One of the most striking and important features of the SAARC decision-making procedure is that, though formally bilateral issues are excluded from the domain of the SAARC, it has been more or less a ritual on the parts of the SAARC leaders, especially India to discuss bilateral issues of utmost urgency during the summit on an informal basis (Basu Ray Chaudhury 2006).

externalization of bilateral disputes or encouraging external actors' mediation adopted by some South Asian states are essentially to limit India's sphere of influence in the sub-region. It has been argued by some experts that this is in contrast to the theories of smaller nations pursuing a 'bandwagoning'[67] strategy by forming an alliance with the regional hegemon, in this case India. With the exception of Bhutan, the other BBIN countries– Nepal and Bangladesh– have not followed the strategy of bandwagoning with respect to energy cooperation (Dash 2001). Rather in more recent times, China has emerged as the largest investor in the Bangladeshi energy sector (Siddique 2019).[68] China is also making inroads into the Nepali energy[69] sector through loans worth US$ 90 millions for the development of the Upper Trishuli 1 hydropower project (Asian Infrastructure Investment Bank 2019). In order to assert its regional power and also to counter growing influence of China, India continues to resort to bilateralism. There are also examples of disputes with its seemingly friendly neighbours such as the issue over the Farraka barrage between India and Bangladesh (Rahman, Islam, Navera, *et al*. 2019), and the discontent surrounding the Mahakali treaty with Nepal (Bagale and Adhikari 2020) that have created a fractured geopolitical landscape in the sub-regional milieu. This has been a major factor that has strengthened the mutual acrimony and distrust, and prevented regionalism among the BBIN nations (Dash 2001).

India's consistent refusal to give land access to Bangladesh to import electricity from Nepal and Bhutan through its territory has withheld progress on energy cooperation in the region. It was one of the major reasons that led to the shelving of the Myanmar–Bangladesh–India (MBI) pipeline in 2005. The deal was not completed because of India's refusal to agree to the Bangladesh's demands of transmission of hydropower from Nepal and Bhutan through Indian territory, a corridor for supply of commodities between Nepal, Bhutan and Bangladesh, and adoption of necessary measures to reduce trade imbalance between the two countries (Lama 2020). Another major political factor was

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67 In international relationsbandwagoning refers to a situation when a state aligns with a stronger regional power. It does so when it conceives that the costs of opposing a stronger regional power far exceed the benefits (Mearsheimer 2001).

68 According to estimates by the Bangladesh Bank, total Chinese FDI into Bangladesh in fiscal year 2019 was US$ 1159.42 million (or US$ 1.16 billion). Of this, the net inflow of FDI into the power sector was US$ 960.59 million. In other words, Chinese investments into the Bangladesh power sector accounts for 82.8% of total Chinese FDI into the country (Kibria 2019).

69 According to the Department of Industry, Government of Nepal, the total proposed amount of foreign investment upto fiscal year 2019–20 by China (Mainland) was Rs 120,354.79 million (i.e. Rs 120 billion). This involved a total of 1668 projects. During the same period, total investment proposed by India was Rs 98,538.31 million (Rs 98 billion) covering 802 projects (Government of Nepal, 2020).China accounts for a significant share of total FDI into Nepal. In recent times, Chinese FDI into Nepal is clustered in energy-based industries (Gautam 2018).

the refusal to engage in any meaningful cooperation with India by the KhaledaZia-led Bangladesh National Party (2001–06). There were major security concerns between India and Bangladesh over the latter's providing shelter to Indian militants from the north-eastern region of India during that period (Lama 2020). However, the tide started changing when India's cooperative diplomacy with Bangladesh gained momentum. India agreed to Bangladesh's three demands within the next six years when the Bangladesh–India Framework Agreement of 2011 was signed after Sheikh Hasina became the Prime Minister in 2006. Although the agreement seeks to foster deeper cooperation in trade, investment, water resources, electricity generation, transmission and distribution among several other developmental objectives, the progress of long-term energy projects between these two countries did not take off in the expected manner (Government of India 2011). Despite renewed attempts at cooperation between India and Bangladesh, following Sheikh Hasina's election (second term), the trilateral MBI pipeline, however, could not be retrieved as China National Petroleum Corporation had already signed a 30-year hydrocarbon purchase and sale agreement with the Daewoo International in December 2008 to draw gas from the Shwe gas project located offshore in the Bay of Bengal. The pipeline became operational in 2013 and by 2019 China had imported 3.4 million tonne of gas from Myanmar valued at US$ 1.76 billion (Lama 2020).

In this context it is important to consider how resource politics has emerged as a major geopolitical factor that has hindered the BBIN countries from realising the potential of energy cooperation. In post-colonial South Asia, the notion of nationalism is reflexive in nature where the nationalism of one South Asian country is articulated only vis-a-vis that of another South Asian country. As a result, to South Asian countries the region matters only for articulating nationalism and defining nationalism in terms of distancing itself from other neighbouring country. Consequently, the region lacks its own solidarity (Basu Ray Chaudhury 2009). BBIN sub-region also suffers from the same ailment. Since cross-border cooperation implies that certain resources, geographical locations, and even physical and social mosaic are shared among the neighbours, it requires BBIN countries to relinquish national control over some of the shared resources such as gas for Bangladesh and water resources for Nepal. Concerns over the loss of sovereignty, however, brought about an element of reluctance and introduced withdrawal syndrome from the regional cooperation process. This has been amply reflected in an array of negotiations on gas with Bangladesh and hydel power projects like Karnali, Pancheswar and Rapti with Nepal (Lama 2007). At the outset, one may observe that geopolitical barriers to energy cooperation among BBIN can be attributed to the manifestation of mistrust, but deeper analysis will suggest that at the heart of this problem is the nature of domestic politics in these countries. Political parties in each country try to legitimize their support by spreading hatred and animosity towards the neighbouring states. Quite naturally then the lack thereof of sufficient political will act as major impediments to regional energy cooperation.

» **Political constraints in domestic milieu as hindrance in promoting cross-border cooperation**

Foreign policy is a subset of domestic policy. It is evident repeatedly in the cases of political leaders in Bangladesh, Nepal, and India who have used energy resources in their respective constituencies to further their electoral agenda. Therefore, these agendas are seldom in favour of regional energy cooperation. The politicians have not evoked the necessary response from the population and this is partly because they have not made the case for such cooperation (Huda 2020). For instance, political rivalry between the Awami League (AL) and the Bangladesh Nationalist Party (BNP) has led to a highly politicized foreign policy. This has resulted in misrepresentation of the country's interests. Although India-Bangladesh relations have reached new heights in the last two decades of AL rule, the Citizenship Amendment Act (CAA) passed by India in December 2019 has put its relationship with the AL regime in a quagmire (Chakravarty 2019). It is yet to strain the relationship between the two countries to a point of no return, but given the highly polarized nature of domestic politics, the opposition led by BNP could use the issue of CAA as political leverage.[70] Similarly, turbulent domestic politics in Nepal has undermined the prospects of regional energy cooperation. Constant feuding between the major political parties–the Communist Party of Nepal-Maoists (CPN-M), the Unified Marxist Leninist (UML) and the Nepali Congress (NC)–had prevented the drafting of a constitution until 2015. Amid growing challenges to strike a balance between India, China, and the United States, Nepal is engaged in formulating its foreign policy. Under the guidelines laid out in the constitution, Nepal's foreign policy envisions reviewing past treaties and bilateral agreements based on mutual trust and equality. Along with border issues, another major sticking point between Nepal and India relations has been the insistence by the former for the amendment of the 1950 Peace and Friendship treaty, a bedrock of bilateral relations between the two (Bhattarai 2020). The recent border issue (on Kalapani) between Nepal and India, which has put a strain on bilateral relations, could have been conjured due to growing internal crisis faced by the Nepali Prime Minister K.P. Sharma Oli.[71] Developments

70 This is already evident from the statements made by the Secretary General of the BNP, MirzhaFakhrul Islam Alamgir, that people in Bangladesh are worried about the CAA and National Register of Citizenship (NRC) exercise in neighbouring Assam, and criticized the AL- led government for keeping silent on the issue (The Daily Star 2019).

71 Although India has been engaged in building infrastructure in the disputed region earlier, the timing of the May 8, 2020, announcement by India, of the 80 km long road connecting to the border with China at Lipulekh, with Prime Minister Oli's domestic political situation may have triggered the issue (Xavier 2020).

such as these are likely to create pressure on the leaders in domestic politics. And with anti-India sentiments running high in the country following the 2015 blockade, it is more likely that future cooperation on energy and other matters may face challenges due to this anti-India rhetoric that is gradually developing. Furthermore, it has also paved the way for increasing Chinese influence in the Nepali energy sector (Baral 2016). These internal and external factors could play a major role in preventing domestic politicians in Nepal showing the desired political will to engage in energy cooperation with India.

The federal structure of India also puts domestic political issues at the heart of regional energy cooperation. A pertinent example of this is the discontent expressed in local newspapers regarding the Baharampur (West Bengal, India)–Bheramara (Bangladesh) electricity transmission line, especially when shortfalls exist in the Indian domestic market. This dichotomy of exporting energy despite local populations suffering from 'blackouts' is another major impediment to energy cooperation. Local politicians view the energy resources as something that should be *divided* and *not shared*, preventing any progress on energy cooperation (Huda 2013). The opposition by Mamata Banerjee, the Chief Minister of West Bengal, India to the agreement between the Government of Bangladesh and India on Teesta river water sharing in 2011 and 2017 highlights this case further (Majumdar 2017).

The inherent link between energy and electoral politics in India, Bangladesh, Nepal, and Bhutan has led to the perception of energy as a political good rather than an economic good, which can change the situation for betterment of common people across borders. The political labelling of energy has led to the failure to account for the economic cost of non-cooperation. Resource nationalism in these countries has led to a misinterpretation of the costs and benefits of resources by the politicians. For example, when Indian companies signed production-sharing contracts with Dhaka to explore hydrocarbons in the Bay of Bengal in 2014, the political rhetoric focused on the need to control these energy resources as strategic assets and not on the objective of cooperation and utilization for ensuring broader objectives of energy security and human development in the region (Huda 2020).

Further, there is a gap between researchers and policymakers. While technocrats are more focused on technical issues such as cost-benefit analysis, the policymakers are more concerned with their electoral base and political implications. The gap in communication between these two groups must be bridged.

» **Environmental security**

In addition to the above factors, sub-regional energy cooperation is also contingent upon traditional security issues, socio-economic security of the population living in the border areas through which major transmission lines pass, and environmental security. Policymakers in India, Bangladesh, and Nepal have varied views on environmental impacts of the various trilateral and bilateral projects being planned. While Bangladesh and India consider hydroelectric projects as economically and environmentally desirable, the policymakers of Nepal, without undermining the economic benefits, highlight the possible negative impacts of these projects on the natural environment within their country. This discrepancy in the perception of environmental security between the hydroelectricity-producing countries and the importing countries is a major impediment to sub-regional energy cooperation among BBIN countries.[72] Another major case at hand where sharing of trans-boundary natural resources is directly related to political conflicts is the discussions regarding the Pancheswar Multipurpose Project (PMP) (Das Gupta 2020).[73]

Environmental security is also a major factor in India's bilateral engagement with Bhutan–a country which has enjoyed relatively stable political relationship with India. But Bhutan's objective and adherence to the concept of gross national happiness, with conservation of nature as one of the primary pillars of development, has put it at odds with countries like India and Bangladesh. Several studies have highlighted the immense hydropotential of Bhutan. However, when one considers the feasibility of such projects on grounds of ecological and environmental issues, the actual potential may be lesser than those

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72 In fact, according to Dipak Gyawali, the former Minister of Water Resources of Nepal, India is not only interested in importing hydroelectricity from Nepal, but also its interests lie in regulating the rivers flowing into India from Nepal. Regulating the flow of rivers has significant benefits in terms of irrigation, flood control, and navigation. However, New Delhi is yet to acknowledge these (Huda 2020). India has been unwilling to account for external costs and benefits of the several projects between the two countries. This has been a major impediment to multi-lateral hydroelectric projects involving the two countries.

73 The PMP was envisaged 24 years ago under the Mahakali treaty between India and Nepal in 1996. But discussions are still ongoing and the two countries are yet to break a deadlock regarding the sharing of water from River Mahakali, and the allocation of project costs based on the expected benefits from the multipurpose project. Furthermore, Kalapani, the source of River Mahakali, is one of the disputed border areas included by Nepal in its new political map in 2020. This has added a new dimension to the Indo-Nepal political crisis with adverse implications for regional cooperation initiatives.

estimated. For instance, the 1200 MW Punatsangchul project, with an estimated cost of US$ 1.875 billion, envisaged in collaboration with India, has raised environmental issues. The blasting and tunneling for the Punatsangchhu I and II projects– the two largest dams under construction in Bhutan– have caused widespread environmental disruption to forests and river systems, and destroyed the habitats of the endangered white bellied heron and golden mahseer, a rare species of Himalayan carp (Walker 2015).[74]

Similar environmental concerns have emerged over a coal-based power plant built at Rampal in Bangladesh, in collaboration with the National Thermal Power Corporation of India and Bangladesh Power Development Board.[75] Although important from a strategic point of view, the environmental connotations may hinder energy cooperation between India and Bangladesh.

Concluding observation

The aforesaid pressing issues prevailing in BBIN are also relevant for BIMSTEC. Political conflicts and impediments to cross-border energy cooperation can only be overcome through changes in the domestic political environment in the member countries of BBIN as well as BIMSTEC, on the one hand, and by strengthening mutual understanding for the sake of common people on the other hand. Indeed, the domestic factors are important in this regard, nonetheless it is also imperative to take into account several external factors that play an important role in fostering or hindering cross-border energy cooperation.

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74 Furthermore, a recent study by Dini et al. (2020) has shown that the area with active displacements impinging on thePunatsangchul dam site has continuously increased in size since 2007 and into 2018, even though stabilization measures have been implemented since 2013. Stabilization measures currently only focus on a small portion of the slope andthe unstable area is larger than previously evaluated. Highly damaged rock is present across many areas of the entire valley flank, indicating that the volumes involved may be orders of magnitude higher than the area on which stabilization efforts have been concentrated after the 2013 failure (Dini, Manconi, Loewet al. 2020). Similarly. the reservoir-based dam over the River Sankoshhas been a priority of Bhutanese Prime Minister LotayTshering. But an issue over a proposed canal as part of the project has gone unmentioned. The canal is supposed to run through the Buxa tiger reserve in the Indian state of West Bengal into RiverTeesta. According to an initial assessment report by the Wildlife Protection Society of India (WPSI), the proposed 60 m wide, 141 kmlong canal would cut right through the Buxa tiger reserve, creating an unbridgeable gap for elephants, tigers and other wildlife in the region. Although the dimensions of the Sankosh river project havebeen changed, no information on the canal is present in public domain. Any such large intervention in West Bengal is likely to increase conflicts at the state and federal levels of government- adding a subnational component to the conflict.

75 The plant has been facing pressure from environment groups as the plant poses a serious threat to the integrity of the Sundarban's ecosystem. The 1320-MW plant site at Rampal in Bangladesh sits 14 kmfrom the boundary of the Sundarbans Reserve Forest (Ghosh 2018).

As already highlighted earlier, countries in the BIMSTEC sub-grouping have high external dependency for energy supply, especially oil. Majority of oil imports by India and Bangladesh is through maritime routes. Consequently, regular supply of oil to India and Bangladesh must pass through the major maritime 'choke points' such as the strait of Hormuz and the Malacca strait. This is likely to endanger the energy security of countries dependent on energy imports through these routes.

Under the prevailing circumstances, energy security of these countries has been intertwined with maritime security (Basu Ray Chaudhury and Basu 2016). India gets over 70% of its oil supplies across the sea routes of the Indian Ocean (Parthasarathy, 2019). China also receives 80% of its oil imports through the Malacca strait- the busiest chokepoint in the Indian Ocean, and also through the Arabian Sea and the Bay of Bengal (Weber, 2019). As a result, any conflict in the Indian Ocean region increases the vulnerability of China and India's energy security objectives. This has been one of the key drivers of Chinese investments, through the Belt and Road Initiative (BRI) projects, in Sri Lanka, Bangladesh and Myanmar. Further, there is a prevailing apprehension that these investments also serve dual-use purpose as security buffers apart from securing energy access. China has been using its economic clout to offer credits for infrastructure projects, leading recipients into a 'debt trap' (Parthasarathy 2019). For example, China is sparing no effort to expand the Myanmar Port of Kyaukpyu in the Bay of Bengal. This port is linked to its Yunnan province by pipelines across Myanmar. China has also emerged as a major investor in the energy sectors in Nepal and Bangladesh (Kibria 2019; Government of Nepal 2020).

In order to balance the growing presence of China in the Bay region, India and other countries like Japan and the United States of America have also increased their cooperative initiatives in BIMSTEC, in general, and in the BBIN sub-region, in particular. With India being wary of Chinese investments in its neighbours, there is a possibility that rivalry between the two Asian giants may hinder sub-regional cooperation- as each tries to assert its influence in the Bay region. In this context, India needs to play a proactive role both in BBIN and in BIMSTEC, keeping the importance of the Bay in its vision for wider Indo-Pacific in consideration. There is a need for more cohesive and functional engagements among the members within BIMSTEC for strengthening sub-regional solidarity, especially in the domain of energy security for the sake of human security.

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CHAPTER 9

Indo–German Energy Cooperation: The Case of Wind Energy

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Wind power has matured as a cost-effective technology resulting in its expanding share in energy generation and intensified innovation activities. In terms of installed wind power capacity, India belongs to the top five nations globally. In general, India has emerged as a lead market for frugal innovations targeted at achieving "affordable green excellence", which has allowed the country to make strides also in the field of wind power. Nonetheless, the wind sector in India also faces some significant challenges in exploiting its full potential in terms of capacity installation and actual utilization. Germany is an established lead market for wind energy and it is also confronted with challenges related to market expansion. Joining hands by these two countries can create win-win effects going beyond their own territorial boundaries.

This chapter explores potential avenues of intensified cooperation between India and Germany in the wind power sector and proposes a framework for potential Indo-German bilateral cooperation that could encompass working together on repowering and technology upgradation, co-shaping the future with collaborative innovation, overcoming the cost barrier with economies of scale, and applying frugal solutions in the global markets. This potential can, however, only be tapped with support from institutional stakeholders as certain challenges cannot be overcome by private sector enterprises alone.

Introduction

Over the last decade, India has experienced sustained growth of GDP, along with the rise in per capita power consumption which accompanies increasing prosperity and urbanisation. These trends are placing [an] enormous demand on India's energy resources – and are a key driver for the Indian government's mission to increase renewable energy capacity to 450 GW by 2030 (GWEC, 2020).

The above statement of the Global Wind Energy Council (GWEC) underscores the drivers and inter alia also the challenges associated with the transformation that the energy sector is undergoing in India. In recent years, the country has emerged as a leading nation in the use of renewable sources of energy. In terms of cumulative renewable energy capacity, India reportedly overtook Germany and was preceded only by China, the United States of America (USA), and Brazil at year-end 2019 (REN21, 2020: 46). This capacity enhancement has been enabled by substantial capital investments. According to some estimates, India has witnessed new investments worth 112.6 billion USD in renewable power and fuels between 2007 and 2019, whilst more than 64 billion USD have been invested since 2014 after the present government under Prime Minister Narendra Modi assumed office (REN21, 2018: 2020).

This is not surprising, as rising energy demand and political ambition are both core drivers for the expected sustained market growth (GWEC, 2020). Under the Paris Agreement, India has committed to reduce the emission intensity of its gross domestic product (GDP) by about one-third from the 2005 level by 2030. Moreover, India has pledged to increase the share of renewable energies in its cumulative installed capacity to about 40% by 2030 subject to international help in the form of transfer of technology and low cost finance (MNRE, 2021a). Following the objective of providing affordable access to energy for all citizens, the incumbent Indian government has set an ambitious target of installing 175 GW (gigawatt) of renewable energy capacity by 2022 and 450 GW by 2030, of which wind power is expected to contribute 60 GW by 2022 and 150 GW by 2030 (MNRE, 2020a; Tanti, 2020). Wind and solar power have emerged as two most cost-competitive sources of power on the grid, with per unit prices reported as low as ₹1.99 (less than 3 US Cents) for solar power and ₹3.00 (about 4 US cents) for wind power in fiscal year 2020-21 (MNRE, 2021a). Sources of renewable power are nowadays nearly 35% more cost-effective than the conventional fossil fuels (GWEC, 2020).

With the installed wind power capacity of 38.6 GW at year-end 2020, India belonged to the group of top four wind power nations (MNRE, 2021a: 46). Wind power has globally matured as a cost-effective technology resulting in its expanding share in energy generation and intensified innovation activities. Nonetheless, the wind power sector in India also faces some significant challenges. For example, the estimated national potential of 302 GW at 100 m above ground level (AGL) still remains largely unexploited, and the installed capacity does not fully translate into actual utilization. The share of wind power in total electricity generation stood at 4.5% at the end of the fiscal year 2018-19, even though wind energy accounted for about 10.7% of the installed power generated capacity in the country (CEA, 2019b; 2020b). The low bidding prices coupled with some implementation issues discussed in the later sections of this chapter have negatively impacted the business attractiveness of the Indian wind sector of late, which has slowed down new capacity addition.

Against this backdrop, this chapter explores avenues of cooperation between India and Germany. The study is embedded in the context of the lead market theory which states that certain countries or regions are endowed with factors that enhance the possibility of a global diffusion of their innovative products in specific industries (Beise, 2004). Germany, with a proven base of technological capabilities in this industry, is considered as one of the established global lead markets for wind power (Beise and Rennings, 2005). However, a certain saturation can be observed, as good sites for onshore wind power become increasingly scarce (BMWi, 2018). On the other hand, India has emerged as a lead market for frugal solutions that are targeted at achieving affordable excellence by substantially reducing the total cost of ownership (Herstatt and Tiwari, 2017). Frugal innovations have the potential to enable reaching the goal of affordable access to clean energy globally and can constitute a cornerstone of Indo-German cooperation as will be argued in this chapter.

The chapter is structured in four sections: After setting the study context in Section 1, the reader is familiarized with the status quo and long-term development trends in India's wind power sector in Section 2, which also deals with the opportunities and challenges existing there. This section closes with a SWOT analysis. Section 3 maps the potential for Indo-German collaboration. After a brief overview of the German wind power sector and its research thrust areas, technology trends are discussed. This is followed by examples of existing bilateral collaboration and an analysis of future cooperation avenues in the light of opportunities and challenges identified earlier. A framework for potential Indo-German bilateral cooperation in wind sector is proposed. The chapter concludes with a summary in Section 4.

Wind Power Sector in India

Wind power potential

Studies by National Institute of Wind Energy (NIWE) suggest that India's wind power potential at 100 m hub height stands at approximately 302 GW (NIWE, 2021) and is highly concentrated in Southern and Western India with a share of approximately 51% and 34%, respectively. Gujarat, Karnataka, Maharashtra, Andhra Pradesh, Tamil Nadu, and Rajasthan, in this order, are the top six states accounting for nearly 94% of the national wind power potential (see Table 1). Madhya Pradesh in Central India also possesses considerable wind potential. However, nearly 80% of this potential is on cultivable land, which makes it quite difficult, if not impossible, to actually exploit this potential. Even though Odisha also shows some potential (3 GW), the possibilities on the eastern coast of India seem to have remained, to some extent, underexplored (cf. NIWE, 2021).

Furthermore, studies suggest that the national wind power potential more than doubles to 695 GW at 120 m above ground level (NIWE, 2019), signifying a much greater potential than currently targeted. Exploiting this potential, however, requires affordable solutions due to steeply increasing costs correlating with the increased hub height. Another challenge for actual utilization lies in the fact that out of this estimated 695 GW potential only 340 GW is available on wasteland, while 347 GW is on cultivable land and another 8 GW on forest land (NIWE, 2019: 25). Actual utilization of wind power capacity on cultivable and forest land poses major societal dilemmas and challenges, such as implications for food security, right to private property, and ecological sustainability. They could also lead to protests from other interest groups with legitimate concerns such as farmers or environmental activists (cf. Dai, Bergot, Liang, *et al.*, 2015).

TABLE 1: Wind power potential at 100 m hub height (in MW)

No.	State	Rank I (wasteland)	Rank II (cultivable land)	Rank III (forest land)	Total (MW)
1	Gujarat	52,288	32,038	106	84,431
2	Karnataka	15,202	39,803	852	55,857
3	Maharashtra	31,155	13,747	492	45,394
4	Andhra Pradesh	22,525	20,538	1165	44,229
5	Tamil Nadu	11,251	22,153	395	33,800
6	Rajasthan	15,415	3,343	13	18,770
7	Madhya Pradesh	2,216	8,259	9	10,484
8	Telangana	887	3,348	9	4,244
9	Odisha	1,666	1,267	160	3,093
10	Kerala	333	1,103	264	1,700
–	Others	82	144	24	250
–	**Total**	**153,020**	**145,743**	**3,489**	**302,251**

Source: Own illustration based on NIWE (2021). For detailed methodological information, refer to https://niwe.res.in/department_wra_100m%20agl.php

Status quo and trends in capacity installation

At the end of September 2020, the total installed base of renewable sources of energy in India was 89.2 GW. This amounted to nearly one-quarter (23.7%) of the total installed capacity in the country (373 GW) as per official figures released by the Central Electricity Authority (CEA, 2020a). The southern and western regions accounted for the bulk of the installed renewable energy capacity with a share of approximately 48% and 30%, respectively. The data further reveal that wind power constituted the most important component of the installed base of the renewable energy sector in India with a share of about 43%, followed closely by solar power (40%) and more distantly by bio power and small hydro (see Figure 1).

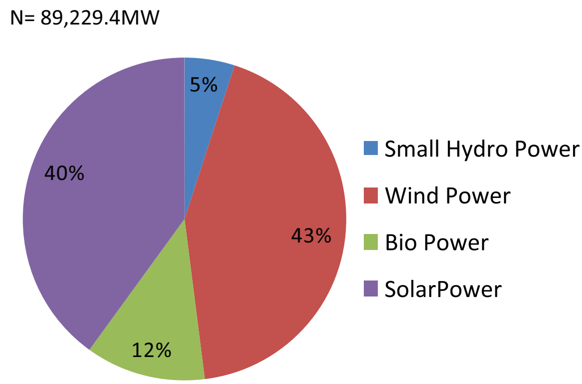

FIGURE 1: Composition of the installed renewable energy base in India at the end of September 2020

Source: Author's illustration based on CEA (2020a) data

*The term "bio power" in this chapter refers to power generated from biomass including both bagasse and industrial waste.

The installed wind power capacity has risen almost exponentially since the turn of the millennium from a small base of 220 MW in year 2000 to 38.1 GW by September 2020 (Figure 2, right axis). The cumulative growth in this period amounts to a compounded annual growth rate (CAGR) of 29.4%. In the past decade, as the absolute volume of installed capacity has increased the growth momentum has slowed down, but the CAGR has still been in double digits (11.3%). The amount of new additions has been, however, somewhat cyclical and has reduced sharply since 2018 after witnessing the peak of 4148 MW in 2017 (Figure 2, left axis).

Decline in new additions can be attributed to increasingly lower prices and implementation issues (IWTMA, 2020). For example, according to REN21, a global renewable energy community of stakeholders representing science, governments, NGOs and industry, "Another 8.6 GW was in the active pipeline at year's end, but many wind (and other) power projects have been delayed by problems obtaining land and accessing transmission lines" (REN21, 2020: 133). The challenges surrounding this sector are discussed in more detail in Section 2.7.

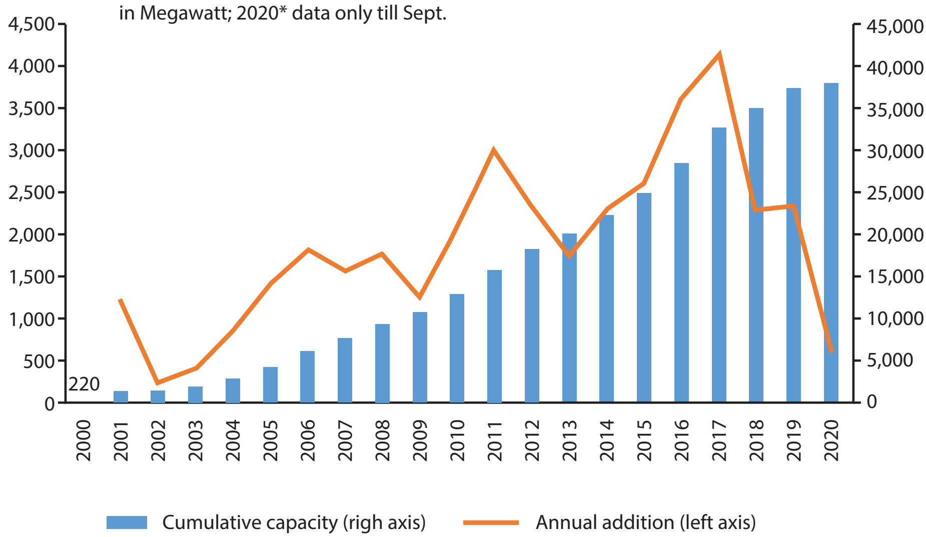

FIGURE 2: Growth in India's installed base of wind power (2000–2019).

Source: Own compilation and illustration based on Jethani (2017), CEA (2019a); 2020a), and Statista (2019).

Wind power generation

In FY 2018-19, wind power contributed over 62 billion units (BU) to power generation in India,[76] accounting for a 4.5% share in the country's total power generation (Figure 3). Wind power generation has nearly doubled in the 5-year period between FY 2014-15 and FY 2018-19, growing from a base of 33.8 BU. Wind power generation has registered a CAGR of 16.4% in this period and has grown at a much higher rate than the overall power generation (5.5%). As a result, wind's share in total power generation has increased from 3% to 4.5% in this period. Nevertheless, the current share of wind power to national power generation (4.5%) continues to be lower than the global average of 5.9% in 2019 (REN21, 2020).

[76] In FY 2019-20, wind power generation increased to 64.6 BU as per GOI-MNRE (2021a). Data for the full fiscal year for all indicators were, however, not available at the publicly available data dashboard of the CEA at the time of finalizing this report in the first half of May 2021. The term "billion units" is comparable to "terawatt hours" (TWh).

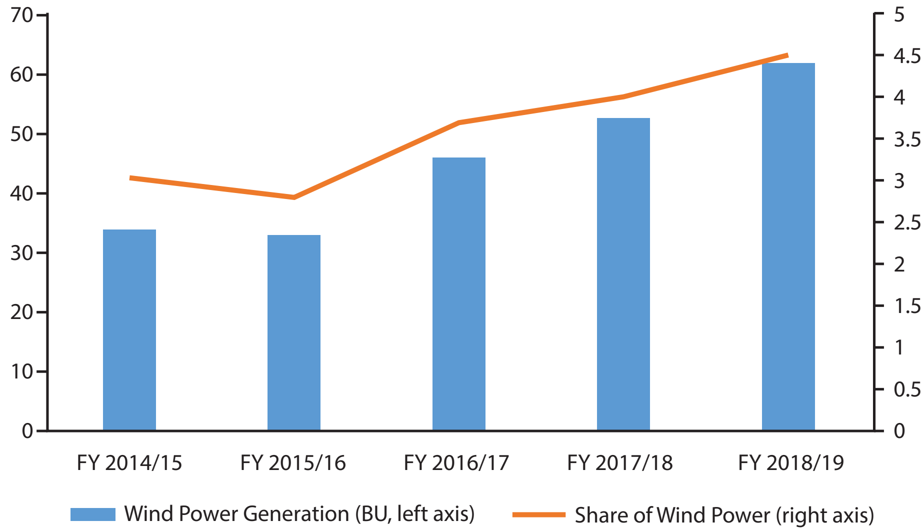

FIGURE 3: Wind power generation in India from FY 2014-15 to FY 2018-19.

Source: Own compilation and illustration based on GOI-CEA (2018); 2019b).

Also, within the overall group of renewable energies, wind continues to remain the most important source of power generation as can be seen in Table 2. The contribution of renewable sources of energy to the power generation has more than doubled in the past 5 years. The growth has been mainly driven by wind and solar power, while the contribution of bio power and small hydro in absolute terms has been relatively stagnant. Truly outstanding growth has come from solar power, whose power generation has grown nearly nine times in the past 5 years. However, it must be noted that solar power has also grown from a lower starting base.

As a result, the share of wind power in the generation of renewable energy has decreased from 55% in FY 2014-15 to 49% in FY 2018-10, while the share of solar power has grown robustly from less than 5% to nearly 35%. Even though there may be some useful lessons to learn from the growth story of solar power in India, it must be remembered that the wind sector's share in the actual renewable energy generation (~47%) still continues to remain above average relative to the installed capacity (43%) within the group of renewable sources of energy. While solar has been rapidly catching up, it still has to further enhance its efficiency to match its share in the installed capacity (40%; see Figure 1).

TABLE 2: Patterns of power generation by renewable sources (in BU)

Fiscal	Wind power	Solar power	Bio power	Small hydro	All renewables	
					Sum	Growth
FY 2014-15	33.77	4.60	14.94	8.06	61.37	–
FY 2015-16	33.03	7.45	16.68	8.35	65.51	6.7%
FY 2016-17	46.00	13.50	14.16	7.67	81.34	24.2%
FY 2017-18	52.67	25.87	15.25	7.69	101.48	24.8%
FY 2018-19	62.36	39.27	16.33	8.70	126.76	24.9%
FY 2019-20*	64.76	49.56	14.56	9.35	138.21	9.0%
Share in FY 2019-20	46.9%	35.9%	10.4%	6.8%	100%	–

Source: Own compilation based on (GOI-CEA, 2018; 2019b; 2021).

**Data refer to the first 11 months of FY 2018-19. As of May 9, 2021, data going beyond February 2020 were not available on the CEA Dashboard.*

Performance of Indian states in utilizing wind power potential

A closer look at the performance of the top 10 Indian states with the highest wind power potential at 100 m AGL reveals a very mixed picture in terms of installed capacity and power generation (see Table 3). Utilization of the wind potential by the top two states, that is, Gujarat and Karnataka, languishes at a higher single-digit figure. The best utilization at 27.5% has been achieved by Tamil Nadu, followed by Madhya Pradesh (24%) and Rajasthan (~23%). Kerala, Telangana, and Odisha are at the bottom of the list with low single-digit figures despite their relatively high potential in the national context. Odisha with an installed capacity of merely 0.02 MW has practically not utilized its relatively large potential of more than 3 GW.

Reasons for this under-exploitation of potential vary across states. In the case of Karnataka, the problem is rather structural since much of the potential (~73%) is concentrated in cultivable or forest land, which makes it difficult to acquire land. In Odisha, the problem seems to be the rather weak business ecosystem in the region as almost 54% of the wind potential is available on wasteland.

This analysis also has certain implications for future: Tamil Nadu seems to be reaching a saturation point as it has utilized over 27% of its overall wind power potential in terms of installed capacity, whereas only 33% of the potential is available on wasteland. This is also relevant for Madhya Pradesh, where only 21% of the wind power potential is available on wasteland and already 24% of the potential has been

TABLE 3: Performance of selected states in utilizing wind power's potential

Sl. No.	State	Estimated potential (100m AGL; MW)	Installed capacity (31.03.2020; MW)	Utilized potential*	Power generation (BU)
1	Gujarat	84,431	7,542	8.9%	10,628.8
2	Karnataka	55,857	4,791	8.6%	8,727.8
3	Maharashtra	45,394	5,000	11.0%	7,027.4
4	Andhra Pradesh	44,229	4,092	9.3%	6,633.9
5	Tamil Nadu	33,800	9,304	27.5%	12,560.5
6	Rajasthan	18,770	4,300	22.9%	4,913.9
7	Madhya Pradesh	10,484	2,520	24.0%	3,555.1
8	Telangana	4,244	128	3.0%	183.4
9	Odisha	3,093	0.02	0.0%	54.7
10	Kerala	1,700	63	3.7%	99.5
	Total for India	**302,251**	**38,124#**	**12.6%**	**61,243.2**

Source: Own compilation based on Table 1 in this chapter, InWEA (2021), GOI-MNRE (2021b), and GOI-CEA (2021).

**Utilized potential is defined here as the share of installed capacity in the total estimated potential.*

#Data refer to September 2020.

utilized. On the other hand, Rajasthan seems to still possess a lot of untapped potential despite the relatively high share of utilization (~23%). More than 82% of the available potential in Rajasthan is on wasteland, and so many opportunities seem to still exist there.

This analysis also shows that India needs to increasingly shift its focus to tap wind power potential at higher hub heights of 120 m and above at existing locations to better utilize the available land resources without jeopardizing its food security, environmental diversity, or social harmony. Out of the total wind power potential of 695 GW at 120 m AGL, a substantial chunk 340 GW (~49%) is on wasteland, and there is a better chance of actually realizing this potential. For this purpose, it may be also useful to promote hybrid wind–solar projects. The government has already initiated steps to tap this potential. According to the National Wind-Solar Hybrid Policy, which was released in May 2018, solar and wind resources can be seen as complementary to each other in India due to given geographic conditions and hybridization of these two technologies can help in ensuring optimal utilization of the physical infrastructure, such as land and transmission systems (MNRE, 2018).

Emphasis on innovation

There has been an added emphasis on research and development (R&D) and innovation. Ministry of New and Renewable Energy (MNRE) has identified thrust areas of the wind energy sector in offshore wind, potential assessment, forecasting and scheduling, material development, and cost reduction technologies, where it supports R&D projects under the Renewable Energy Research and Technology Development Programme (Purohit and Purohit, 2009; MNRE, 2020b). MNRE has increased its in-house R&D expenditure in the past two decades from ₹123 million ($2,7 million) in FY 2000-01 to ₹345 million ($5.4 million) in FY 2017-18 (DST, 2020).

In addition, wind turbine manufacturers such as Suzlon conduct in-house technology development. According to Suzlon's annual report for FY 2019-20, the company spent approximately ₹1.4 billion ($20.1 million) on R&D. Several other global majors, such as Siemens Gamesa, Vestas, and Nordex, have been developing country-specific solutions. Such solutions often focus on enhancing economic affordability, and there have been innovative ideas like the use of entirely lattice or hybrid towers that have a tubular steel portion combined with lattice sections to achieve greater tub height at a more affordable cost. Such innovations are likely to foster better utilization of wind power potential, which is significantly higher at 120 m AGL or above as discussed in the previous section.

Opportunities for wind power in India

India's wind power sector is endowed with several substantial opportunities. Key power sector stakeholders in India, including power utilities from public and private sectors, have made commitments to reach the target of zero emissions or to transit to 100% use of renewables (REN21, 2020). The currently installed wind capacity in the country (38.6 GW) still has to go a long way to reach the estimated total potential of 302 GW at 100 m level or the 695 GW at 120 m level. In addition, India has a large coastline of about 7600 km where the potential of offshore wind remains largely untapped. Studies conducted in Gujarat and Tamil Nadu indicate that these states possess strong potential for offshore wind power. According to MNRE, eight zones in each of these two states have been identified as possessing strong wind power potential to the tune of 70 GW (MNRE, 2021a: 52). Government has declared its intention of developing 5 GW of offshore wind energy project by 2022 and 30 GW by 2030 (MNRE, 2020a), which opens new investment opportunities. It is a reasonable presumption that similar potential can be unearthed in other coastal states, such as Maharashtra, Kerala, Andhra Pradesh, Karnataka, or Odisha. Preliminary estimates of cost of offshore wind power in Tamil Nadu have suggested costs of about ₹12–13 per unit, which is around four times higher than tariffs currently offered for onshore wind (Srikanth and Kandavel, 2015). Therefore, there seems to be a strong need for achieving economies of scale/scope and concerted R&D efforts to tap this potential.

As mentioned in Section 2.4, India has started an initiative to integrate solar and wind power plants to create hybrid power plants to enhance output and increase reliability of production. A recent study on integrating solar and onshore and offshore wind power into India's energy system, published in *Nature Communications*, comes to the conclusion that wind and solar together "could meet 80% of anticipated 2040 power demand" in India provided the trend of decreasing cost can be maintained (Lu, Sherman, Chen, 2020). The authors argue that costs for renewable energy sources are "projected to decline significantly in the future, in response to technological improvements and benefits from learning experience" (Lu, Sherman, Chen, 2020: 9).

From a macroeconomic perspective too, there is an enormous potential for growth due to unsaturated market demand from both consumer households and the industry in a growing economy. According to CEA data, per capita consumption of electricity in India has more than doubled between FY 2002-03 and FY 2019-20, growing from 567 kWh to 1208 kWh. A comparison with the World Bank data from the year 2014 shows that advanced economies generally have a much higher per capita comparison of electricity. For example, per capita electricity consumption in the USA stood at 12,997 kWh, in Germany at 7035 kWh, in Malaysia at 4652 kWh, and in China at 3927 kWh. Figure 4 shows a comparison of India's per capita energy consumption with the average values for different groups of countries based on their economic advancement in the year 2014.

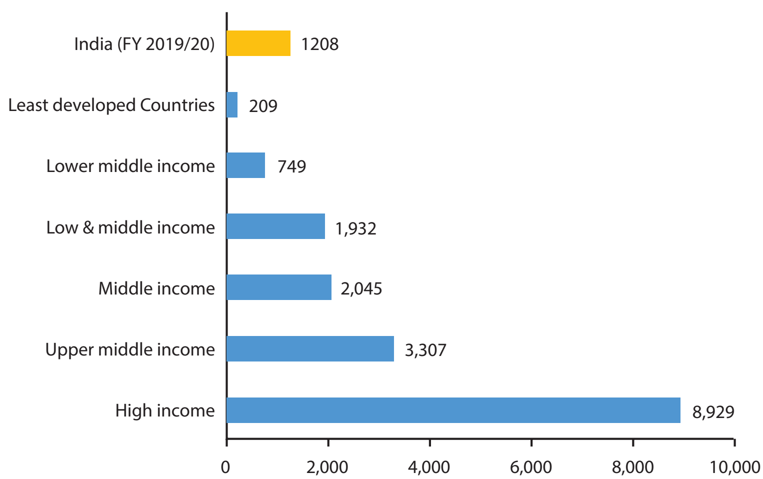

FIGURE 4: Per capita consumption of electricity in different groups of countries in 2014.

Source: Own illustration based on GOI-CEA (2020b) and World Bank (2020).

Note for data on India, refer to FY 2019-20 and for all other economic groups to year 2014.

Figure 5 also underscores the fact that despite the substantial GDP growth of the previous two decades, India is still a long way away from the status of a middle-income country. Therefore, it is a reasonable presumption that the increasing economic activity of a young and growing population, coupled with the challenge of climate change and an increasing emphasis on electric mobility, whether in the automotive sector or for the railways, will continue to increase the demand for electricity and inter alia for renewable energies for the next many years, if not decades. A more detailed discussion on key drivers of demand for energy in India can be found in Tiwari and Tiwari (2019).

In addition, the developments of the previous two decades have created a vibrant ecosystem in India, which includes about domestic and global wind turbine manufacturers that produce more than 30 different wind turbine models in India. The current annual manufacturing capacity of wind turbines in the country is estimated at between 8 and 10 GW (MNRE, 2020a). About 4000 SMEs are estimated to be active in India and the wind power sector employs about 60,500 people (REN21, 2018; Suzlon, 2018). Production in the country is able to achieve a localization level of up to 80%, which reduces the need for imports.

The "Make in India" initiative of the Government of India, according to estimates by Indian Wind Turbine Manufacturers Association (IWTMA), has attracted over 40 manufacturing units to India and enabled investments worth approximately $4 billion (Tanti, 2018). India has also emerged as a global market leader in affordable solutions in wind power (Bhagwat and Tiwari, 2017; REN21, 2018). Solutions created for the extremely price-sensitive Indian market can be utilized in other markets with comparable socio-economic conditions.

Challenges faced by wind power

As mentioned previously, the wind power sector in India has recently faced problems affecting addition of new capacities. Challenges can include both project development risks and operational risks (IEA, 2020). According to results of a panel discussion titled "What is ailing wind industry today" organized by IWTMA, challenges include a "very low and unviable" pricing (in some cases as low as ₹2.44 or USD 0.03) that negatively affects the business proposition for the operator and reduces banks' willingness to fund projects. Furthermore, according to IWTMA, "developers are missing from the value chain in the projects to do the work of land acquisition, wind resource assessment, road construction, sub-station construction, etc" (IWTMA, 2020).

Similar problems are reported by REN21, which states: "Although the issuance of tenders remained strong in India during 2019, many were cancelled or undersubscribed, and projects that were already tendered faced delays (due to efforts to renegotiate for lower tariffs or to outright withdrawal of existing PPAs [Power Purchase Agreement]), which have held up turbine deliveries and put significant pressure on the domestic manufacturing industry" (REN21, 2020).

GWEC (2020) also sees several market barriers "preventing renewable energy auctions from functioning well, approved projects from being executed and wind energy from being deployed at the necessary pace to meet public targets". Furthermore, there have been reports of policy uncertainties, infrastructure constraints, delayed payments for generation, and lack of available land in good wind areas, resulting in higher geographic concentration of installations (REN21, 2020). According to a recent report by news agency Press Trust of India (PTI), the amount owed by distribution companies (discoms) to power generation firms increased by a further 29% within 1 year to ₹1381.87 billion (approximately $19.5 billion) in October 2020 (Economic Times, 2020), which confirms the issues related to payment delays. Moreover, there have been reports of renewable energy project delays due to failure of discoms to sign power purchase agreements for offtake of power generated from projects already awarded in a tender process affecting on-time execution of projects (Azure Power, 2020). Also, concerns related to low prices and the resultant worries regarding financial viability were confirmed by a report in the *Economic Times* with the title "Spain's Acciona and Germany's Nordex bearish on India's wind energy prospects". The newspaper reported that Acciona has decided to "no longer participate in wind auctions in India [...]" as it did not "want to get into a bidding war" (Chandrasekaran, 2020). For further insightful and detailed discussions on challenges related to India's energy sector, see Ahn and Graczyk (2012) and IEA (2020: 114–118).[77]

In addition, India also faces challenges in the actual utilization of the installed capacity for power generation, which is still below the global average of about 6% (Tiwari and Tiwari, 2019). To achieve this, there is a need for technology upgradation. Many wind-rich sites in India are still using turbines that are nearly 30 years old and no more in optimal working condition due to lack of spare parts and proper maintenance (Nair, 2020). The improvement in turbine technology in the previous two decades has significantly increased the average capacity utilisation factor (CUF) from around 20% to up to 40% (Nair, 2020). Repowering such turbines could improve the productivity in India's wind power sector substantially. According to a study conducted by Idam Infrastructure Advisory on behalf of the Indo-German Energy Forum (IGEF), "[..] more than 10 GW of old wind turbines having less than 1 MW capacity are installed in very wind rich class 1 sites, while another 2.5 GW are installed with less than 500 KW turbine capacity" (Krishnajith, Joshi, Mary, *et al.*, 2018). The study suggests that repowering these old wind turbines with modern turbines could "more than quadruple the energy generation on these sites".

[77] For a generic understanding of the economic issues involved in the wind sector that are crucial for the success of the business model involved, see Mathew (2006).

Furthermore, smaller transaction size has been reported as one of the challenges facing India's renewable energy sector in general (IEA, 2020). Indian wind power market is highly fragmented with many small wind park operators that often face financial constraints. There is a need for infusion of more capital and creation of economies of scale to fully exploit the potential of wind power without compromising on its affordability. This is, however, contingent on solving policy and efficiency related matters. MNRE has announced several measures, such as setting up of a Dispute Resolution Committee (DRC) that includes outside members to redress disputes as well as "a robust Payment Security Mechanism involving Letters of Credit and Government Guarantees" (MNRE, 2021a: 6-7). The effectiveness of these measures has yet to be confirmed but they, at least, seem to be steps in the right direction.

A SWOT summary

The opportunities and challenges discussed above are summarized in a SWOT table of strengths, weaknesses, opportunities, and threats faced by the wind power sector in India (Table 4). This summary is used subsequently to map out the potential for Indo-German cooperation in Section 3.4.

TABLE 4: A SWOT analysis of India's wind power sector

Strengths	Weaknesses
» Market size	» Low profitability
» A well-established ecosystem	» Smaller transaction sizes
» Presence of domestic and global players	» Strong geographic concentration
» Political vision and institutional support	» Partly outdated turbines
» Technological capabilities	» Contract enforcement
Opportunities	**Threats**
» Strong potential for domestic growth	» Low prices and aggressive bidding
» Learning opportunities	» Availability of land (at suitable sites)
» Lead market potential for exports	» Project implementation issues
» Cooperation in technology development	» On-time execution and cost control
» Repowering of old turbines	» Suboptimal capacity utilization

Potential for Indo-German cooperation

Brief overview of the German wind power sector

Germany is regarded as a lead market for renewable energies in general and for wind power in particular (Beise and Rennings, 2005; Jänicke, 2005; Schleich and Walz, 2018). At the end of 2019, gross generation of electricity via wind power stood at 131.8 TWh (terawatt hours) in Germany making wind power the largest source of electricity generation, with a share of approximately 21% in the total power generation (BWE, n.d.). Within the European Union, Germany has the third highest share in wind power in the domestic gross power generation behind Denmark (57%) and Ireland (32%) (REN21, 2020). The installed capacity on onshore wind energy as of year-end 2019 was 53.9 GW operationalized via 29,456 wind turbines.

In addition, over 1500 offshore wind turbines with a capacity base of 7.8 GW were operational as of June-end 2020 (Deutsche WindGuard, 2020). The average wind turbine generator (WTG) in the first-half of 2020 had a turbine capacity of 3319 kW with a rotor diameter of 121 m, hub height of 137 m, and tip height of 197 m, which require more space than old WTGs. A positive impact of modern WTGs is that a small number of WTGs can result in the same or higher energy yield (Deutsche WindGuard, 2020).

The lead market position of Germany in the wind energy sector is driven by strong R&D and innovation activities involving private sector enterprises, universities, and other research institutions with substantial financial support from the state (Tiwari and Tiwari, 2019). Intensive R&D efforts have enabled the industry to increase the performance of onshore wind turbines by more than 10-fold since the early 1990s (BWE, 2015). Between 2012 and 2019, the federal government provided research funding worth €454 million to wind power sector. The funding pattern shows an emphasis on research on wind farm development, followed by research on offshore energy, logistics, installations, maintenance and operations, and wind physics and meteorology. The research funding is aimed at further reducing the cost of producing electricity from wind energy and enhancing the reliability of wind turbines (BMWi, 2020).

The research objective followed by the government appears to be shared by private sector firms and is complemented by corporate R&D. For example, the wind turbine manufacturer Nordex spent €189 million on R&D in 2019, which amounted to about 5.7% of their annual sales. In the firm's own words: "Efficient wind turbines that enable cost-effective power production for their entire operational lifecycle allow the Nordex Group to maintain its competitive strength" (Nordex, 2020: 35).

Technology trends

Cost reduction and performance improvement can be seen as two core drivers of the growing demand for wind power (CEMAC, 2017). Technological developments have enabled wind power to make significant advances in optimum power generation from available wind and thus gain market acceptance (Purohit and Purohit, 2009). Firms are increasingly turning to longer blades and taller towers to capture more energy from the wind and reduce costs of wind turbines and wind systems (CEMAC, 2016). New technological developments and economies of scale are expected to reduce costs by as much as 58% from current levels by 2050 (BNEF, 2018).

Digital technologies are affecting market design, business models, and system operations and thereby "changing the boundaries and dynamics of the industry and helping to optimize renewables assets" (IRENA, 2019: 11). Technologies such as Internet of Things (IoT), artificial intelligence, big data, and blockchain are driving these changes. Digital technologies in the wind power sector operate on four key fronts: turbine productivity, wind farm commissioning, manufacturing processes, and ancillary services (Siemens Gamesa, 2019: 20). Their (positive) impact can be summarized in four categories, that is, efficiency effects, performance effects, service enhancement, and maintenance effects, which are generated, for example, by technologies for real-time monitoring, predictive maintenance, better scheduling, and use of digital twins for optimization. As a result, they allow high (multidimensional) affordability, high target specificity, and effective utilization of resources that constitute the frugality effects of digital transformation (Tiwari, 2021).

Examples of existing bilateral collaboration

India and Germany have engaged in close bilateral cooperation regarding renewable energies in general, including in the wind power sector. For example, MNRE and the German Corporation for International Cooperation (*German: Deutsche Gesellschaft für Internationale Zusammenarbeit*; GIZ) have co-initiated three major projects, namely, Green Energy Corridor (GEC), Access to Energy in Rural Areas (ACCESS), and Integration of Renewable Energies (I-RE), into the Indian electricity system (Tiwari and Tiwari, 2019). The GEC, for example, is targeted at creating suitable nation-wide electricity transmission infrastructure for renewable power. This is especially important because much of the wind power potential in India is concentrated in a few wind-rich states and the generated power has to be transmitted to users located elsewhere in the country. For this, strengthening of both intra-state and inter-state transmission infrastructure is required (Chaurasiya, Warudkar, and Ahmed, 2019). MNRE and GIZ have also set up an Indo-German Energy

Forum, which is based in New Delhi and is mandated to promote "private sector activities and putting in place an enabling environment so as to further develop the market for power plant technologies, energy efficiency and renewable energies in India" (IGEF, 2019).

There are several German wind power companies active in India, such as Nordex, Enercon, Siemens, Siemens Gamesa, and Senvion. Similarly, India's Suzlon is active in Germany with its two locations in Hamburg and Rostock and is using Germany as a technology hub to learn from the German lead market. German firms, such as Senvion, are using India for technology and product development to create market-specific solutions. For example, according to a statement by Senvion India Pvt. Ltd.: "Senvion has decided to not only grow in India but also tap on the intellectual strength of the country by opening its largest R&D facility in Bangalore outside of Germany. [...] Senvion will undertake project development work and provide full turnkey solutions in India along with its latest turbines offering with an intent to consistently reduce LCoE [Levelized Cost of Energy] year over year and therefore meet our customers' business cases" (Senvion, 2020).

Similarly, Siemens Gamesa is in the process of introducing its next generation wind turbine the SG 3.4-145 into the Indian market. This new wind turbine, as per firm's own information, is "specifically designed and optimized for wind conditions in the country, and has a clear objective to deliver the lowest possible Levelized Cost of Energy (LCoE) with high reliability. The turbine is strongly positioned to cater to the needs of the auction market and aims to further drive the growth of wind power in India" (Siemens Gamesa, 2020). The company is planning to manufacture this wind turbine in India beginning in early 2021.

Analysis of future cooperation avenues

This section analyses avenues of potential bilateral cooperation for India and Germany in the light of strengths, weaknesses, opportunities, and threats of India's wind power sector identified in the SWOT analysis (see Table 4). German companies face an increasingly saturated domestic market with limited opportunities for substantial further expansion in the field of onshore wind due to the progressively decreasing number of suitable onshore sites (Tiwari and Tiwari, 2019). On the other hand, India's (renewable) energy market is characterized by a still very low per capita electricity consumption and is set to grow exponentially for a long time to come. Even when the Indian market is extremely cost-sensitive and the prevalent low prices make the business proposition appear unviable at times, bilateral collaboration may prove very promising for both sides for the following reasons:

1. **Need for repowering and technology upgradation:** A substantial number of India's wind turbines need repowering, which would enhance the amount and reliability of

power generation. India, at present, faces an uphill task in optimizing actual power generation from its installed capacity base. Germany has achieved a remarkable utilization of its wind power potential: 126 TWh of generated power and a 21% share in national power generation. Even when wind conditions are vastly different in both countries and can account for a substantial part of the difference, India could probably achieve a greater share of wind in actual power generation than the current 4.5% in generated power. A collaboration in this sphere would allow India a better cost structure and more financial manoeuvring space, while German firms could get access to a relatively large, existing market. Taller towers and digital technologies could also help India exploit its wind power potential in a socially non-disruptive manner.

2. **Co-shaping the future:** Technology development and digital transformation of the wind power value chain are likely to keep on further reducing the operational and investment costs while enabling better performance. Therefore, innovating firms are anyway likely to meet the requirement of cost reduction in future through technological advancement. Joining forces and creating shared know-how reduces market and technological risk of innovation projects. Wind power sector is increasingly undergoing a digital transformation (Awasthi, 2020). A recent study of digital transformation strategies of the world's largest wind turbine manufacturers suggests that firms in emerging market economies act faster in adopting digital technologies due to less path dependencies and the possibilities of cost reduction (Tiwari, 2021). India with its thriving information technology sector and engineering R&D services can prove to be a crucial partner for developing next generation solutions based on the concept of "affordable green excellence", also known as frugal innovation. Collaborating in open innovation networks outside firm and sectoral and national boundaries can enable a win-win proposition. The Indo-German bilateral cooperation should also include Indian firms' engagement in Germany.

3. **Overcoming cost barriers with economies of scale:** Developing a market with huge future potential such as India, in conjunction with its lead market potential, can enable significant economies of scale (and also economies of scope) that would further decrease unit costs and enhance competitiveness of businesses as well as of the wind sector in general. Even though prima facie German companies are confronted with a cost barrier, resulting from high price sensitivity of the Indian market and their own high operational costs, gaining entry to a large market could help them to reduce unit costs and improve their cost structure for both existing and future products. Instruments like forward pricing can help flatten the cost curve. Technological expertise, industry experience, and resource endowment may

provide German firms with a competitive advantage in getting a foothold in the Indian market and then to subsequently seek economies of scale.

4. **Unlocking lead market potential with frugal solutions:** Even though falling prices are opening new global markets, the transition to auctions and tenders has led to intense price competition and reduced the number and diversity of participants (REN21, 2020: 131). Solutions that meet the specific needs of the Indian market in terms of prevalent geographic and economic conditions (affordable green excellence) can lead to learning curve effects and enhance the demand for such products after requisite adaptation in other comparable markets. This could open new business avenues for both Indian and German partners. Frugal solutions, with their high emphasis on monetary, societal, infrastructural, and environmental affordability, are increasingly demanded globally. Meeting sustainable development goals (SDGs) in the developing economies of Asia, Africa, or South America presents both a humanitarian imperative and a commercial opportunity (Tiwari and Tiwari, 2019). Currently, just 10 nations account for 85% of the installed global wind power capacity. Frugal solutions in the entire value chain of wind power can enhance access to energy in an environmentally sustainable manner, for example, in the form of "distributed renewables for energy access" (DREA) systems. These include mini-grids and off-grid solutions and might also involve "pay-as-you-go" business models (REN21, 2018). India is a known lead market for affordable excellence, where just during 2016-17 more than 200 mini-grid systems were installed (REN21, 2018). According to a report, India has the lowest total investment costs for onshore wind power, while many nations in Africa, Central America, or South America are confronted with some of the highest costs (REN21, 2018: 122). Collaborative efforts at innovative frugal solutions could create win-win situations for all stakeholders and for environment.

It, therefore, appears recommendable to enter the India market in a suitable form depending on the firm-specific context to gain a foothold, for example, with a joint venture or technology collaboration. These key factors are summarized in a potential framework for Indo-German bilateral cooperation in the wind sector (see Figure 5).

Finally, this framework of potential Indo-German bilateral cooperation in wind sector can be achieved only if suitable framework conditions are created. The framework conditions are contingent upon another set of challenges that cannot be resolved by firms alone. Difficulties faced by firms in contract enforcement, availability of land, and the resultant problems in on-time execution pose a big barrier for private sector firms and resolving them is generally outside their sphere of influence. These problems need to be addressed by institutional actors. A study by REN21 to assess the feasibility of securing 100%

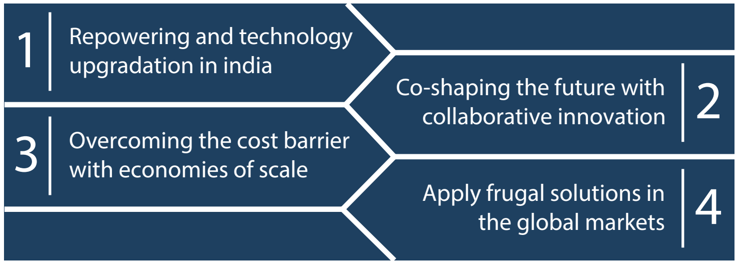

FIGURE 5: A framework for Indo-German bilateral cooperation in wind sector.

Source: Tiwari and Tiwari (2019)

renewable energy for India and the challenges associated with this objective identified "a clear need for special assistance from developed countries, especially in relation to grid integration of wind and solar electricity, and operation and maintenance of renewable power generation" (REN21, 2017: 21).

Indian and German stakeholders from the government and industry side need to create mechanisms that can streamline the auction and tendering processes, cut bureaucratic hurdles, remove non-tariff barriers, and reduce the risk of unplanned delays and deferred payments to incentivize firms for more engagement. In addition, it also needs to clearly define the parameters of investment security granted to foreign direct investment projects. Unstable, and seemingly arbitrary, regulatory conditions as seen, for example, in the case of Vodafone's investment in India, where tax laws were changed in 2012 with retrospective effects for past 50 years after an unfavourable judgement from India's own Supreme Court and where India even now continues to contest a ruling by the Hague-based Permanent Court of Arbitration, seem to have created uncertainties that need redressal at the policy level (Aulakh, 2020; Singh, 2020; Khan, 2021). Resolving these matters with urgency is in own interest of India.

Summary

This chapter set out to explore the potential of bilateral cooperation between India and Germany. For this purpose, it first investigated the status quo and trends in India's wind power sector. With very ambitious targets for renewable energy set by the government, India has emerged as a leading nation in terms of installed wind power capacity with an increasing share of wind power in the national electricity generation at highly affordable rates of as low as $0.03 per unit. The vast and expanding market is expected to remain unsaturated for many more years to come. Nevertheless, the country has recently also faced challenges in maintaining the pace of capacity additions. Auctions and tenders have remained undersubscribed, partly due to the immense cost pressure that has arisen for firms. In addition, there are other challenges in better utilization of capacities for actual power generation or for maintaining on-time execution of projects, for example, due to problems in land acquisition.

Germany is a leading nation in the field of wind power with substantial technological capabilities. However, there has been a saturation effect in the field of onshore wind power as good sites have become increasingly scarce. Mapping of opportunities and challenges in the Indian wind sector shows that a bilateral cooperation can be mutually rewarding. India needs repowering and technology upgradation of a substantial number of its wind turbine generators. It also requires taller towers at 120 m AGL or above to overcome problems associated with acquiring sites on cultivable or forest lands. Here, it is possible to enter into a partnership that could increase power generation at windy sites in a more cost-effective way, while allowing German firms to participate in a large volume market.

Levelized costs of energy (LCoE) are expected to keep falling due to technological advancement in future. Therefore, firms should not be afraid to enter a highly cost-sensitive market like India. Since costs are anyway expected to keep falling, it makes business sense to gain an early foothold in one of the largest global markets. Firms could rather engage proactively in collaborative innovation to co-shape the future. Cost pressure can be utilized as an incentive for resource-constrained frugal innovations in open global innovation networks to reduce market and technology uncertainty. The large market size also allows a significant advantage in terms of potential economies of scale that can be leveraged to overcome the cost barrier.

Finally, an Indo-German partnership has the potential to move beyond the national boundaries of the two countries. Frugal solutions based on affordable green excellence are increasingly demanded in all parts of the world and can help achieve the SDG #7 of affordable and clean energy for all. Especially, countries with comparable socio-economic conditions to that of India can be targeted by such frugal solutions. Moreover, there is an increasing need for such products also in the industrialized economies due to financial and environmental constraints.

This potential is, however, not realized without active help and support from institutional stakeholders as several challenges facing the Indian wind power sector require concerted policy and regulatory measures. Institutional players from the India and Germany would need to work together to reduce market risks for German companies arising out of, for example, project delays due to land acquisition problems or delayed payments by power distributors. A stable and supporting institutional framework is of critical relevance for operating in a highly price-sensitive market that requires extremely cost-effective management of operations.

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CHAPTER 10

Establishing Multilateral Institutions to Promote Clean Energy - Case of International Solar Alliance

A Commentary

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Multilateral institutions have been an integral part of the global energy governance landscape. From the formation of OPEC to IRENA, several institutions were formed to govern and regulate the market, prices, supply chain, reduce monopolistic strategies, and to enhance cooperation amongst its members and those dependent on these institutions for access to natural resources.

With the increasing need to address climate change, mitigative solutions such as the adoption of renewable energy are imperative and a prerequisite to avert the impending crisis. Amongst the various renewable energy resources, solar energy has witnessed exponential growth and has immense potential for further expansion. While several institutions such as IRENA, REN21, REEEP have been formed to address opportunities and challenges for the renewable energy industry as a whole, the International Solar Alliance (ISA) is the first intergovernmental organization dedicated to a single renewable resource. It brings together countries that have abundant solar potential with an urgent need to increase their utilization of solar energy in their energy mix.

Since amendment to the framework agreement in 2018 to universalize its membership, the the alliance has grown exponentially in the past few years. In July 2020, 87 countries had signed the Framework Agreement of the ISA and of these 67 have deposited their instruments of ratification. The Alliance began with Tropic of Cancer located members and in 2018 changed to universalization, opening its membership to all countries highlighting its transformation into an international organization. The universalization led to an opportunity for countries with technological impetus, energy importers and private stakeholders to cooperate with countries that have high solar potential.

The universalization of the International Solar Alliance (ISA) also highlights the need for the alliance to be more robust and evolve into a dynamic multilateral institution that reforms and transforms itself in accordance with the changes in the renewable energy industry. It needs to get into established norms, standards, good practices and implementation mechanisms that are globally acceptable. The ambitious One Sun, One World, One Grid (OSOWOG) could be the step towards creating a vigorous multilateral institution that does not repeat the shortcomings of other energy institutions while remaining inclusive and ensuring global competitiveness in the renewable energy industry. The Alliance was also granted observer status by United Nations in 2021, strengthening its global position and supporting its core objectives for accelerating solar energy (The Hindu, 2021). The observer status also strengthens ISA's role as an International energy organization that is attracting more members each year.

The paper would briefly examine the inception of the ISA, the transformations that have occurred since its inception in 2015, the differences, challenges, and opportunities for a nascent multilateral institution in a polycentric energy landscape. It would also encapsulate and examine India's growing role in the ISA and the benefits as well as the burden of steering an expanding global institution. It would also provide a policy road map to enhance its multilateralism approach while securing a strong global position. The paper would be divided into four parts:

1. Brief overview of global energy institutions, the formation of ISA, what is different or similar with other institutions
2. Navigating a polycentric energy landscape – with different types of institutions with each one having a different set of stakeholders
3. India's role in ISA and how this role is perceived globally
4. Short policy roadmap on how it could enhance its multilateralism imprint

Global Scenario

The current global political scenario is polycentric in its form and functioning. With the lack of a single unilateral power, the need to conform to one idea, principle or practice is not prevalent as a norm. Each country also has an option to choose strategic and trading partners more freely than before leading to possibilities for greater cooperation and collaboration. Since the end of cold war, the powerful roles of USA and Russia has receded while China has emerged as a strong economic powerhouse, yet there is no single unilateral force in the International regime. The lack of unilateral power also brings its own challenges and disadvantages, yet the current global political scenario has significant room for countries to shape their foreign policy. With no single unified superpower, the polycentric nature of global politics is essential to address global challenges like climate change- while it brings new complexities, it also has led to the development of intricate interdependent relationships among countries and stakeholders. This is particularly evident in the area of renewable energy. According to Scholten et.al 2020, the Renewable energy global landscape has less oligopolistic global markets. It has blurred the distinction between producers and consumers leading to the formation of a new set of pro-sumers. It also provides a large basket of producers to choose from and is more competitive than other markets. According to Scholten et al 2020, Renewable energy is also more inward-looking with countries focusing on tapping internal resources- solar, wind, geothermal etc, this also reduces resource competition.

The need to address global challenges such as COVID-19 pandemic and climate change requires more concerted efforts and has shown how different countries are emerging as leaders in varied aspects ranging from vaccine production, research, and innovation to renewable energy deployment and climate financing.

The current global structure provides a more open field of play for countries to emerge as leaders in specific sectors or issues, creating a layer of multiple narratives and a larger set of norm makers. The global economy is also witnessing diffused global value chain in different sectors ranging from steel, telecommunications to renewable energy manufacturing that is based on interdependences, multiple stakeholders, and without a single country monopolizing the chain. In this evolving global political environment, the energy sector has transformed with climate change implications.

Several institutions are present to govern fossil fuels, with OPEC emerging as one of the key institutions with significant influence on energy markets, prices, and production. International Energy Agency is a significant institution; however, it caters to and encompasses membership of 30 countries from the OECD with an additional 12 more that are either association or accession countries. The IEA also has several conditions and criteria that each member country has to fulfil, hence impacting the membership expansion over the years.

With the rise of renewable energy, one of the first international institutions to emerge was IRENA which was built exclusively for renewable energy expansion globally. It is similar to other UN organizations with an assembly, a council and a secretariat. The focus of the international organization was the advancement and expansion of renewable energy cooperation, knowledge sharing, etc. Renewable Energy and Energy Efficiency Partnership (REEEP) was launched in 2002. It focused on promoting renewable energy in emerging markets. Its membership included governments, civil society, and businesses. The REEEP was launched by the UK and its secretariat was housed at the Foreign and Commonwealth office. Though IRENA is an international organization, REEEP was considered a UN Type II partnership with the inclusion of several stakeholders in its membership. In 2004, it became an international non-governmental organization and in 2016, it was given a quasi-international organization status.

Each organization has mobilized and steered the growth of energy and specifically renewable energy organizations have been critical for the growth of the sector globally. With the increasing call for climate action and reduction of greenhouse gas emissions, the need to accelerate renewables became a priority. Technology advanced economies pushed forward with faster adoption of renewables, especially wind. Most of the developing countries largely fall in the category of solar rich and the need to push this technology in these countries became imperative. Multilateral institutions in the energy sector, specifically in the renewable energy sector have focused on stakeholder engagement, gathering investments and supporting the development of robust markets which is in contrast to fossil fuel focused organisations with a core function to control markets and prices. This stark contrast and the need for an organisation that focuses on solar as a resource, that is particularly abundant in developing countries became an attractive and significant proposition for addressing climate change and energy security.

Emergence of ISA

With the adoption of Sustainable Development Goals (SDGs) in 2015, the need to accelerate the adoption of renewable energy became more important to achieve the Kyoto protocol, Paris agreement and the SDGs. The G20 Antalya summit was the beginning of commitment from India and France to form the ISA to gather the countries between the Tropic of Cancer and Tropic of Capricorn that are solar rich to enable faster deployment of solar energy. The alliance has grown and in 2018 allowed universal membership to all the UN member countries expanding its horizon. The expansion has allowed solar-rich countries to come together with countries that possess finance, technology, and operationalization/deployment experience to work together and achieve high renewable energy targets.

ISA emerged at a time when there was a dire need to steer renewables more robustly and the fact that a developing country like India had taken the mantle to steer the alliance was viewed as a major step by a country, especially that voiced its concerns and limitations in achieving climate commitments with the available finance and technology.

India's role in the formation, functioning, and structure of the ISA is significant and has been pivotal to its growth. As one of the largest solar energy deployers in the world, India is uniquely placed as a country that is neither a major financier, a major manufacturer nor the top technology proponent yet it has adopted renewable energy at a faster rate than many other countries. India has developed a policy ecosystem that fosters renewable energy and has also aided several developing countries to adopt renewables through soft power engagement via the provision of Line of Credit, grants, knowledge sharing, capacity building, and equipment. This engagement has been successful in establishing India's position as an enabler and as strong support for nations that are struggling to deploy renewable energy. The role of India and France in the ISA has also been discussed as two major energy consumers from Global North and Global South coming together to provide a platform for developing and Least developing countries to gain equal representation (Ghatak 2021).

India's focus on 'hand holding' of countries during renewable energy deployment is crucial as it assures countries that the renewable energy implementation would not halt at securing investments and technology but aid them in implementation, operation, and maintenance of the renewable systems ensuring the potential for national-level growth of the sector.

India is an emerging economy; however, it still faces several developmental challenges and needs to achieve several SDG commitments. In spite of its own domestic challenges, India has followed through on its promises on South–South cooperation by aiding other developing nations soft power engagements.

What works in India’s advantage is its stature as emerging economy that has been able to develop a fairly balanced relationship with major powers. As the largest democracy, it has stepped up to fulfil its climate commitments even though it faces social and economic challenges and has risen to be part of several critical global engagements including G20, BRICS, IBSA among others. It also has become a strong global voice demanding developed nations to fulfil their financial commitments under the Kyoto and Paris agreements whilst working vigorously to fulfil its promises. According to the Climate Transparency Report 2020 India is the only G20 country to be on track under its ‘fair share’ evaluation with the potential and initiatives to reach the under 2°C target. During the CoP26, India has committed to a net zero target by 2070, which is a major milestone for a country where millions still lack access to basic amenities besides having the lowest per capita emissions amongst the G20 countries.

In climate negotiations, India has largely been termed or dubbed as a blocker and naysayer and yet it has been significantly active in promoting and implementing clean energy solutions. The country has also emerged as a hub for sustainable innovations and to nurture start-ups in the sustainability space. This position of India has been critical in shaping its engagement and influence as founder of ISA. India is not viewed as an aggressor or a competitor by the member countries and hence has the potential to leverage its role as a facilitator and an initiator in the field of solar energy. India’s role in ISA takes forward its soft power status and equation further. (Shidore et.al, 2019). ISA is also significant example of taking further the notion of global South (Mohapatra, 2019) , with much of its initiatives targeted towards Africa, South America and other Asian economies with high interest in deploying solar energy

So what sets ISA apart from other organizations? ISA is a treaty-based organization, however it is not seeking binding commitments or finances from member nations. Instead it is focusing on creating a conducive environment for solar implementers and building synergies with investors. It has emerged as a unique legitimate platform for all stakeholders to engage and collaborate to promote solar energy.

ISA is also bridging the gaps between solar-rich and finance- and technology- proficient countries. It is providing an atmosphere for businesses, technology institutions, and financing institutes to collaborate and be part of viable business models that allow all stakeholders to grow and develop individually and collectively. The recently launched One Sun, One world, One Grid (OSOWOG) aims to interconnect countries through existing grids. It is an ambitious project and has tremendous potential to transform global energy landscape when implemented.

A view of the future

It is still a nascent organization with significant potential for growth and its footprints need to deepen in the global arena; however, one of the major challenges for ISA has been the continuous perception of the alliance to be very 'Indian' in nature. As a founding member and the host of the secretariat, India has been making efforts to expand its organizational capacities to provide it with the necessary global essence. The recent presence of ISA at CoP26 was a step towards building the initiative with the launch of Green Grids Initiative – OSOWOG (GGI-OSOWOG) which is an evolution of the ISA 's interconnected solar grids initiative. The OSOWOG initiative focuses on global grid connectivity as a means to leverage existing grids and networks rather than propose a new one – a pragmatic idea that requires massive mobilisation. With more than USD 95 trillion slated to be the cumulative investments in the global energy sector by 2050 and with much of the investments to be directed towards energy efficiency, renewable energy and enabling infrastructure. (IRENA, 2019) this initiative has the potential of becoming a reality. If the geopolitical winds are favourable, the grid could pave way for regional integration mechanisms as well.

ISA is making efforts to expand its organizational capacities to take forward its ambitious goals, Though the goal is miles away, the Alliance has done well within the six years of its inception and promises to do more to deal with the global climate urgency. According to Shidore et al, for ISA to enhance its international presence it would require "continued expansion of its solar program, avoiding over-bureaucratization, trained staffing, creation of seamless partnerships with multiple stakeholders, energetic participation of other member states, and rapid progress in achievements and visibility in what is already a crowded renewables ecosystem". ISA needs to actively engage with regional organisations and emerge as a strategic and a natural partner for countries that aim to tap solar energy. It needs to aggressively pursue financing and develop a strong pool of regional level experts who can contribute effectively to implement programmes and initiatives in each of the four regions. A long list of factors and variables that need to be managed and addressed simultaneously with a strategic foresight.

It needs to be acknowledged that the strong linkage between India and ISA will remain core to its success. In contrast to the debate on the need to make it less Indian and more global, the focus should be on how one country has pushed a global agenda that would have massive implications for the climate urgency. Rather than weighing in its financing and geopolitical capacities, the direction of the discussion should be about the drive, motivation, and interest a developing nation has shown in doing something vital to achieve global renewable energy goals.

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