April–June 2020

ENERGY FUTURE

The Complete Energy Magazine

Volume 8 • Issue 3 • Annual ₹800

COVER STORY

INDIA'S ENERGY TRANSITION: THE CHALLENGE WITH DECISION-MAKING AT A TIME OF RAPID CHANGE

FEATURE

GREEN STEEL FOR A GREEN ECONOMY

VIEWPOINT

TRANSITIONING TOWARDS CLEAN ENERGY

teri

From the editor's desk...

Whenever the issue of energy transition is being talked about, it is primarily the electricity generation sector that comes to fore. Undoubtedly, not only the energy sector *per se*, but within that, electricity and heat are responsible for the largest share of GHG emissions. Even NDCs (Nationally Determined Contributions) of countries too have decarbonization of electricity as their key goal. However, since only electricity transition towards decarbonization would not suffice to attain 1.5 °C goal, it is imperative for us to also look at other emissions-intensive sectors and, most importantly, 'harder-to- abate' industrial and transport sectors. Harder-to-abate sectors comprise heavy industry such as cement, steel, aluminium, and plastic industries on the one hand and heavy-duty transportation such as heavy road transport, shipping, and aviation on the other hand. These sectors contribute about 30% of the total global GHG emissions. While power, buildings, and light transport sectors are already being decarbonized, share of emissions from aforementioned industrial sectors and heavy-duty transport is likely to grow unless suitable remedial measures are initiated now.

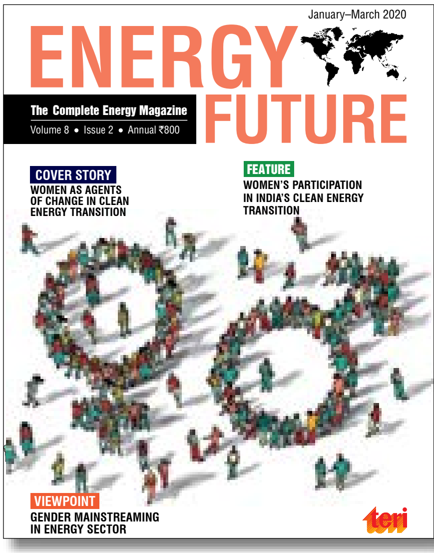
Focussing on these harder-to-abate sectors is also very important for a country like India where substantial investments in new capacities are being planned. Going ahead with business-as-usual approach would only lead to locked-in inefficiencies for decades to come.

However, these transitions to low or zero carbon scenarios need collaborations and coalitions, which in turn predicate on shared visions. While in case of electricity it is all about country and states working in tandem, for 'harder-to-abate' sectors it is collaborations among nations and industries across the globe. Cooperation at multiple levels only can lead us to energy future.

Amit Kumar

Amit Kumar
Senior Director, Social Transformation, TERI

Editor: Amit Kumar Radheyshayam Nigam
Printed and published by Dr Ajay Mathur for The Energy and Resources Institute, Darbari Seth Block, IHC Complex, Lodhi Road, New Delhi- 110 003. Tel. +91(11) 24682100, Fax +91(11) 2468 2144 or Email: teripress@teri.res.in, and printed by Batra Art Press, A-41 Naraina Indl. Area PH- II, New Delhi-28.



teripress@teri.res.in

Letter to the Editor

I enjoyed reading the cover story of the January-March 2020 issue of Energy Future, where the author talks about gender mainstreaming or participation of women in clean energy transition, which can propel social and economic transformation in their communities. Women can definitely act as agents of change because in India, where differences based on gender, caste, class, and ethnicity are embedded in the social fabric and govern the roles, rights, and responsibilities of men and women and the relations between them. Women as agents of change in the clean energy transition can propel social and economic transformation in their communities.

Priyanka Pandey
New Delhi

"The latest issue of Energy Future is a very pertinent one as you have dedicated it to women's participation in India's clean energy transition. I agree with the author that given both the high number and diverse types of jobs that the rooftop solar sector generates, it is well positioned to adopt a gender-inclusive approach to employment, which will attract highly skilled women in particular. There is definitely the need to improve gender diversity and encourage more women to be a part of rooftop solar sector's workforce. All the other articles are also very informative, particularly the article on 'Renewable Energies: Can the Oceans Play a Role?'."

V K Naidu
Secunderabad, Telangana

"The January–March 2020 issue of Energy Future is quite a special one indeed. The article on women in the solar workforce highlights that women SHGs are crucial for the uptake of solar solutions in the informal sector. Through these informal channels, many women have been trained to become entrepreneurs, solar engineers and electricians, and marketing experts. Estimating the number of jobs and its gendered implications is difficult because of the disaggregated and diverse nature of RE solutions, but women have indeed been included into the post-construction phase of the solar sector."

Anil Rampal
Cuttack, Odisha

"I liked reading the feature article on 'Women at the Forefront of Energy Future'. The author has succinctly highlighted the approaches adopted towards involving women in energy supply chain to encourage gender equality in employment and improve the effectiveness of the supply chain. Kudos to your editorial team for publishing such high-quality and well-researched articles for the benefit of the readers."

Aarushi Bhagat
Ahmedabad, Gujarat

Thank you very much for your encouragement. The editorial team of Energy Future will ensure that the magazine caters to your information and knowledge needs. We welcome your suggestions and comments to further improve our content and presentation.

Email: teripress@teri.res.in
Editor
Energy Future

CONTENTS




ENERGY EFFICIENCY SCHEMES LED TO SAVINGS OF AROUND ₹90,000 CRORE: PWC REPORT

The implementation of energy efficiency schemes has led to savings worth about ₹90,000 crore in the FY19, according to official estimates. These numbers are based on a report titled "Impact of energy efficiency measures for the year 2018–2019" by PWC Limited, which was engaged by the Bureau of Energy efficiency (BEE).

This study estimates that various energy efficiency measures have translated into savings worth ₹89,122 crore (approximately) against last year's (2017–2018) savings of ₹53,627 crore. These efforts have also contributed in reducing 151.74 million tonnes (MT) of CO_2 emissions, whereas last year the emissions were lower by 108 MT of CO_2.

Releasing the data through video conference, Minister of State (Independent Charge) for Power and New and Renewable Energy, RK Singh, said: "We have pledged in COP 21 that we will bring down energy intensity of economy by 33 to 35 per cent compared to 2005 levels by 2030. Now, with our energy efficiency initiatives, we have already reduced the energy intensity of our economy by 20 per cent compared to 2005 levels, which is a very good performance indeed." EF

Source: https://www.thehindubusinessline.com/economy/logistics/energy-efficiency-schemes-led-to-savings-of-around-90000-crore-pwc-report/article31520279.ece#

ADANI GREEN PLANS ₹10,000 CRORE CAPEX FOR FY21, EXPECTS DELAYS IN PROJECT EXECUTION

Adani Green Energy plans to invest ₹ 10,000 crore in capital expenditure in the financial year 2020–21, but it expects project execution to be delayed on account of the disruption caused by the COVID-19 pandemic.

Billionaire Gautam Adani led Adani group has committed to invest over 70% of its budgeted capex into clean energy and energy-efficient systems so as to become the largest solar player in the world by 2025 and the largest renewable player in the world by 2030.

"With the long-lasting impact that COVID-19 is due to have on all sectors, sustainability-driven business is imperative. Green energy and renewable energy motivated investments will continue in this coming fiscal year," Gautam Adani, Chairman, said.

Adani Green, which is the clean energy arm of the conglomerate, aims to scale up capacity to 25 GW by 2025 from a portfolio of 6 GW now, which includes projects that are under construction. EF

Source: https://economictimes.indiatimes.com/industry/energy/power/adani-green-plans-rs-10000-crore-capex-for-fy21-expects-delays-in-project-execution/articleshow/75537505.cms

HUGE VARIATIONS IN RENEWABLE POWER AVAILABILITY MAKE GRID-HANDLING HARD IN ANDHRA PRADESH

With drastic changes in the availability of the variable renewable energy (VRE), the Andhra Pradesh State Load Despatch Centre (APSLDC) has written to the Andhra Pradesh Electricity Regulatory Commission (APERC) inferring that "major discrepancies" are making it difficult to handle the grid. The SLDC also said that the differences/changes in the forecast and actual availability were not being predicted by VRE generators. "It is difficult to handle the grid when there is huge variation in the forecast and actual availability. This has become a regular phenomenon and the VRE generators or the qualified coordinating agencies (QCAs) can't provide forecast on these variations on a day-ahead basis," a senior official explained. For the record, the Transmission Corporation of Andhra Pradesh (APTRANSCO) has already proposed amendments to the regulation 4 of 2017 issued by the APERC for forecasting, scheduling and deviation settlement of solar and wind generators for levying deviation charges from qualified coordinating agencies. It said that the state grid was being operated in the range of 5300 MW to 10,170 MW on real time basis with a mix of RE generation of installed capacity 7500 MW. EF

https://www.newindianexpress.com/states/andhra-pradesh/2020/may/03/huge-variations-in-renewable-power-availability-make-grid-handling-hard-in-andhra-pradesh-2138567.html

COVID-19 IMPACT: GREEN ENERGY INSTALLATION TRIPS IN FEBRUARY, MARCH

Only 222 MW of solar capacity and 25 MW of wind capacity were installed in March 2020 as activities came to a halt following the COVID-19 outbreak, and installation would remain slow for another two months, said industry.

In February, only 62 MW of wind projects and 370 MW of solar projects were installed, said the Ministry of New and Renewable Energy (MNRE) officials.

The relatively better showing of solar was mainly due to some projects which should have been commissioned in February but spilled over into March.

"It was in March that everything came to a halt. Supply chain issues intensified. Things dramatically worsened in March although signs may have been visible before that too," said the developer. EF

Source: https://economictimes.indiatimes.com/industry/energy/power/covid-19-impact-green-energy-installation-trips-in-february-march/articleshow/75523548.cms

INDIA ADDS 7.3 GW SOLAR ENERGY CAPACITY IN 2019: REPORT

India added 7.3 GW of solar energy generation capacity in 2019 and holds a strong pipeline of 23.7 GW under construction projects, said a report. Mercom Communications India, a subsidiary of global clean energy communications and consulting firm Mercom Capital Group, released its report 'India Solar Market Leaderboard 2020'.

The report covers market share and shipment rankings across the Indian solar supply chain in 2019. During the calendar year (CY) 2019, India installed 7.3 GW of solar power across the country, consolidating its position as the third largest solar market in the world, it said.

The report reveals that the top ten large-scale project developers account for 68% market share in 2019.

ReNew Power was the top utility-scale developer during 2019, while Azure Power owns the largest project pipeline, the report said. There are around 29 large-scale solar developers with a project pipeline of 100 MW or more in India. EF

Source: https://economictimes.indiatimes.com/industry/energy/power/india-adds-7-3-gw-solar-energy-capacity-in-2019-report/articleshow/75449689.cms

CLEAN ENERGY: GUJARAT, RAJASTHAN SHINE IN FY20 WHILE KARNATAKA RETAINS TOP SLOT

Amid headwinds faced by the renewable energy sector in FY20, Gujarat and Rajasthan managed to add more capacities than others, while Karnataka retained its number one position in the total installed capacity.

Gujarat's total renewable capacity crossed the 10,000 MW mark in FY20, making it the third state after Karnataka and Tamil Nadu to have more than 10 GW of installed capacity, according to a Crisil Research report. It added the highest new capacity of 1934 MW, followed by Rajasthan, which added 1911 MW, the report said. In terms of overall solar energy capacity addition in FY20, the top three states were Rajasthan, Tamil Nadu, and Karnataka. In wind energy, the top three were Gujarat, Tamil Nadu, and Maharashtra.

As on March 31, 2020, India's total renewable capacity stood at 87,028 MW, of which the wind and solar segments accounted for 37,694 MW and 34,627 MW, respectively. EF

Source: https://www.thehindubusinessline.com/economy/clean-energy-gujarat-rajasthan-shines-in-fy20-while-karnataka-retains-top-slot/article31455419.ece

CORONAVIRUS WAKE UP CALL FOR SOLAR INDUSTRY, NEED TO SET UP MORE MANUFACTURING FACILITIES IN INDIA

The COVID-19 pandemic has been a wake-up call for the domestic solar industry as it is heavily dependent on imports, but domestic manufacturing can be sustained only if there is profitability, a senior official of Tata Power Solar said.

As much as 80% of the demand for solar cells and modules are met by imports from Chinese companies.

Therefore, the imposition of work restrictions by China in eight coronavirus-affected provinces, most of which are hubs of solar module manufacturers, impacted the Indian solar industry. The developers are facing a shortfall of raw materials, which is going to affect the installations in the first half of the year.

"This calls for setting up more manufacturing facilities in India. But this will happen only if there is a long-term business proposition," the company's Managing Director and CEO Ashish Khanna said during a webinar. He said that India has the necessary technology, which is at par with global standards, but what is lacking is the scale.

"The government is taking steps by coming up with few manufacturing-linked tenders for setting up solar capacities and has also introduced basic custom duty on imports, but we need a policy framework that will ensure longevity of offtake of the products manufactured as well as the profitability," he said.

Source: https://www.deccanherald.com/business/business-news/coronavirus-wake-up-call-for-solar-industry-need-to-set-up-more-mfg-facilities-in-india-tata-power-solar-official-829115.html

RENEWABLES SECTOR MISSES FY20 TARGET DUE TO HEADWINDS, COVID-19

The renewable energy capacity addition fell short of its target for 2019–20, adding only about three-fourths of the target for the fiscal.

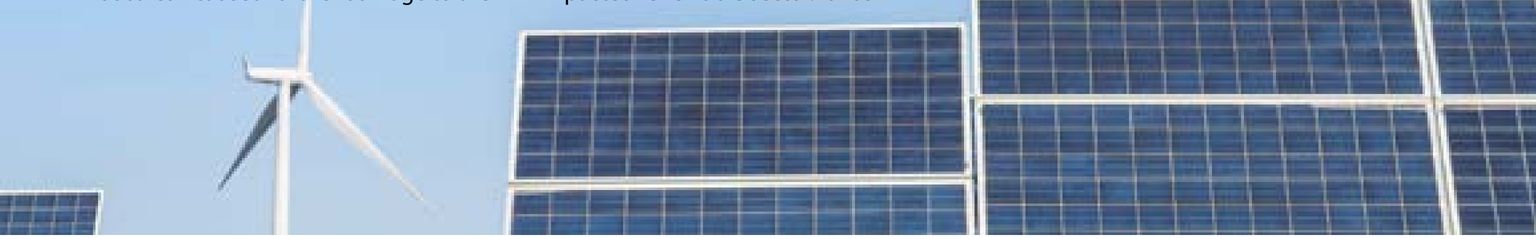
As against the capacity addition target of 11,802 MW for 2019–20, the renewable energy sector added only about 8711 MW or about 74%. In 2018–19, the sector added 8432 MW of new capacity to the grid.

Though the sector was facing many challenges during FY20, the COVID-19 outbreak caused further damage to the capacity addition due to disruption in the supply chain for some parts in the manufacturing of solar modules.

Given the trend in the sector for many years, the second half of the fiscal – the March quarter, in particular – would see most of the new capacity coming into the grid as there will be a rush to complete projects before fiscal year-end. But this year, various factors prevented it.

Meanwhile, the MNRE has been taking various steps to aid the COVID-19 impacted renewable sector. It has granted an extension for renewable projects considering disruption on account of lockdown due to COVID-19 for a period of 30 days beyond lockdown, saying that the situation is to be treated as *force majeure*.

Source: https://www.thehindubusinessline.com/economy/renewables-sector-misses-fy20-target-due-to-headwinds-covid-19/article31413491.ece



CORONAVIRUS CRISIS HITS SOLAR AND WIND ENERGY INDUSTRY

Swinerton Renewable Energy had everything it needed to build a promising new solar farm in Texas. It lined up more than 2000 acres for the $109 million project estimated to generate 400 jobs while under construction. By its completion date, the solar farm was expected to produce 200 MW of energy — enough to power about 25,000 homes — and generate big tax breaks for its investors as part of a government programme to incentivize clean energy.

But the coronavirus pandemic put everything on hold. The solar farm's backers aren't sure they will make enough money from other investments during the pandemic-fuelled downturn for those tax breaks to be worth it. So the project has been delayed by at least six months.

The coronavirus crisis is not only battering the oil and gas industry. It is also drying up capital and disrupting supply chains for businesses trying to move the country towards cleaner sources of energy.

Despite the economic turmoil, climate experts say the coronavirus pandemic could be an opportunity to make drastic shifts in the energy landscape. They say governments around the world should help fund renewable energy and use the turmoil in energy markets to remake the industry and slash carbon dioxide emissions, which will tumble 8% this year, according to the International Energy Agency. EF

Source: https://www.washingtonpost.com/climate-environment/2020/05/04/coronavirus-crisis-hits-solar-wind-energy-industry/

RENEWABLE POWER SURGES AS PANDEMIC SCRAMBLES GLOBAL ENERGY OUTLOOK, NEW REPORT FINDS

The pandemic-induced global economic meltdown has triggered a drop in energy demand and related carbon emissions that could transform how the world gets its energy – even after the disease wanes, according to a report released today by the International Energy Agency (IEA).

The precipitous drop in energy use is unparalleled back to the Great Depression of the 1930s. But not all energy sources are suffering equally. Efforts to shift towards renewable energy could be hastened as fossil fuels, particularly coal and oil, have borne the brunt of the decline. Use of renewable energy, meanwhile, has risen thanks to new projects coming online and the low cost of turning wind turbines or harvesting sunlight.

"The energy industry that emerges from this crisis will be significantly different from the one that came before," predicts Fatih Birol, Executive Director of IEA.

Birol noted that greenhouse gas emissions resumed their upward march following the last economic downturn. He urged governments to put clean energy technologies "at the heart of their plans for economic recovery". EF

Source: https://www.sciencemag.org/news/2020/04/renewable-power-surges-pandemic-scrambles-global-energy-outlook#

CORONAVIRUS AND CLIMATE: AUSTRALIA'S CHANCE TO SHIFT TO GREEN ENERGY

The COVID-19 pandemic is a "huge opportunity" to fast-track Australia's shift towards more renewable energy, climate scientists have told the BBC. Australia's recent bushfires made climate change the country's most pressing issue. Australia looks for ways to revive its economy and innovations around solar, wind, and hydroelectric projects should be central, they say.

The devastating summer of blazes – driven by drought and rising temperatures – killed 33 people and destroyed about 3000 homes. Millions of hectares of bush, forest, and parks burned.

Prof. Mark Howden of the Climate Change Institute at the Australian National University said memories of "the droughts and the fires and the smoke haze across major cities have dissipated with the arrival of COVID-19".

Australia contributes about 1.5% of the world's total carbon emissions. Fossil fuels it exports make up another 3.6% when burned.

Prof. Howden told the BBC that reducing carbon emissions should be put front and centre of Australia's post-virus economic recovery plan. EF

Source https://www.bbc.com/news/world-australia-52395319

$110 TRILLION RENEWABLES STIMULUS PACKAGE COULD CREATE 50 MILLION JOBS

As the world continues to grapple with the worst global pandemic in living memory, economists everywhere are warning that we are witnessing the unravelling of something far grimmer than the 2008 financial crisis.

IRENA director-general Francesco La Camera says COVID-19 has "...exposed deeply embedded vulnerabilities of the current system…" notably the fossil fuel sector which is finding itself in dire straits due to an epic collapse in demand amid a global lockdown. Francesco has opined that the world needs more than a kickstart and that accelerating renewables can potentially achieve multiple economic and social objectives that would help build a more resilient economy.

Beyond 2050 and over the long term, the report identifies investments in 'five key pillars of decarbonization,' namely, electrification, renewable energy generation, system flexibility, green hydrogen, and innovation, as being necessary for the achievement of a near- or zero-carbon global economy. EF

Source: https://oilprice.com/Alternative-Energy/Renewable-Energy/110-Trillion-Renewables-Stimulus-Package-Could-Create-50-Million-Jobs.html

GLOBAL LEADERS MARK CLEAN ENERGY AS 'ESSENTIAL TO ECONOMIC RECOVERY'

World leaders are considering an enhanced use of renewable energy as part of a stimulus plan to revive the global economy post the COVID-19 crisis.

In a roundtable meeting hosted by the International Energy Agency (IEA) and the German Government, the key takeaways were job creation, improving energy systems, and energy efficiency.

The meeting was attended by Amina Mohammed, Deputy Secretary-General of the United Nations; Frans Timmermans, Executive Vice-President of the European Commission; Simonetta Sommaruga, President of Switzerland; and R K Singh, Minister of Power and New & Renewable Energy, Government of India.

The participants lobbied for a more robust public health system and energizing clean energy systems for a faster economic recovery.

Dan Jørgensen, Danish Minister for Climate, Energy and Utilities, said: "In the face of human tragedy and the plethora of consequences of the COVID-19 pandemic, we have also been handed an opportunity to rebuild society in a manner that makes it more resilient to future crises." EF

Source: https://www.energylivenews.com/2020/04/27/global-leaders-mark-clean-energy-as-essential-to-economic-recovery/

RENEWABLES OVERTAKE COAL-FIRED POWER GENERATION FOR FIRST TIME

The International Energy Agency (IEA) report on key electricity trends in the world's developed economies shows renewable energy overtaking coal as a source of electricity generation for the first time in 2019.

Natural gas took the top spot from coal in 2018 and last year coal-fired power production fell by the most on record – in both absolute and relative terms.

Coal use was 13.4% lower than in 2018 at 2328 TWh and made up just over 22% of the total electricity mix. Coal use in Europe fell by 21.7%, the sixth year in a row of shrinking output.

Overall, fossil fuels dropped by 245 TWh, while renewable production rose by 119 TWh from 2018 to 2019. The largest increase for renewable technologies was wind, up by 12.8%, followed by solar, up 14.1%. Nuclear power generation grew slightly.

At 3061 TWh during the year, natural gas remains the leading source of electricity in the 35 countries covered by OECD, and last year electricity produced from natural gas increased by 4.8% and was responsible for 29.0% of the total. EF

Source: https://www.mining.com/renewables-overtake-coal-fired-power-generation-for-first-time/

GREEN ENERGY COULD DRIVE COVID-19 RECOVERY WITH $100TN BOOST

Renewable energy could power an economic recovery from COVID-19 by spurring global GDP gains of almost $100 tn (£80 tn) between now and 2050, according to a report.

The International Renewable Energy Agency found that accelerating investment in renewable energy could generate huge economic benefits while helping to tackle the global climate emergency.

The agency's director general, Francesco La Camera, said the global crisis ignited by the coronavirus outbreak exposed "the deep vulnerabilities of the current system" and urged governments to invest in renewable energy to kickstart economic growth and help meet climate targets.

Investing in renewable energy would deliver global GDP gains of $98tn above a business-as-usual scenario by 2050 by returning between $3 and $8 on every dollar invested.

It would also quadruple the number of jobs in the sector to 42 million over the next 30 years and measurably improve global health and welfare scores, according to the report.

Andrew Steer, chief executive of the World Resources Institute, said: "As the world looks to recover from the current health and economic crises, we face a choice: we can pursue a modern, clean, healthy energy system, or we can go back to the old, polluting ways of doing business. We must choose the former."

Source: https://www.theguardian.com/environment/2020/apr/20/green-energy-could-drive-covid-19-recovery-international-renewable-energy-agency

OIL ROUT SHIFTS FOCUS TO RENEWABLES

As the oil price rout continues, the case for investors and governments to shift more capital to the clean energy sector grows stronger, the International Renewable Energy Agency said in a report. "With the need for energy decarbonization unchanged, such investments can safeguard against short-sighted decisions and greater accumulation of stranded assets," Francesco La Camera, director-general of the intergovernmental organization, wrote in a foreword to the report. Meanwhile, price volatility is undermining the "viability of unconventional oil and gas resources, as well as long-term contracts," he said.

The renewables sector has not been spared from the pandemic's economic fallout, but John Morton, a senior fellow at the Atlantic Council Global Energy Center, said that it appears to be in a relatively solid position.

Calling on governments to design pandemic rescue and stimulus packages that accelerate decarbonization efforts, IRENA presented a scenario for cutting 70% of energy-related carbon dioxide emissions globally by 2050, primarily through using renewables and energy efficiency and a sharp reduction in fossil fuel consumption.

Source: https://www.spglobal.com/marketintelligence/en/news-insights/latest-news-headlines/oil-rout-shifts-focus-to-renewables-58111465

INDIA'S ENERGY TRANSITION

The Challenge with Decision-Making at a Time of Rapid Change

India has set ambitious targets towards the achievement of the dual goals of climate action and sustainable development through its nationally determined contributions and energy access commitments. As India starts a new decade of energy transition, it is an opportune time to assess where India stands in achieving its targets as well as to identify the key challenges being faced during this transition. **Parul Kumar** and **Bharath Jairaj** discuss these issues and offer insights into solutions that can help India achieve its goals.

As national and state governments determine their socio-economic and development plans, India's national and global commitments in the energy sector provide important guidance to policymakers. This article attempts to examine where India stands today in its progress towards achieving these goals, particularly in light of recent challenges in the sector. Along with the need for advancements in the techno-commercial realm of the electricity sector, it is also necessary to tackle the problems of policy uncertainty and acknowledge the specific challenges of specific states. The article examines how issues of governance in the electricity sector can be better addressed, particularly in India's federal context.

India's Energy Transition: Context-Setting

India's energy transition is characterized by its ambitious targets. By the year 2022, India seeks to provide all households in the country 24×7 power. By 2022, India also seeks to install 175 GW of new renewable energy (RE) in the country.[1] These national targets are aligned with India's climate commitments made at the 21st Conference of the Parties of the United Nations Framework Convention on Climate Change (UNFCCC), also known as the Paris Agreement, which came into force in November 2016.[2] Through this landmark international agreement, countries collectively committed themselves to the goals of strengthening the global response to climate change in the context of sustainable development and efforts to eradicate poverty.[3]

India in its Nationally Determined Contributions (NDCs)[4] committed to three targets, which are to be achieved by the year 2030. First, by 2030, 40% of India's cumulative electric power installed capacity will come from non-fossil fuel-based energy sources. Second, India will reduce the emission intensity of its gross domestic product (GDP) by 33–35% (vis-à-vis 2005 levels). Third, India will create an additional carbon sink of 2.5–3 billion tonnes of CO_2 equivalent (through additional forest and tree cover).

In a 2016 report looking at the "future electricity grid",[5] World Resources Institute, Prayas (Energy Group) and others raised the issue of how policymakers in developing countries will find it increasingly difficult to make decisions in a time of rapid change in the energy sector. The report identified the following five key market trends impacting the energy sector in developing countries like India:

1. Unprecedented growth and cost improvements in RE sources
2. Improvements in new technologies and energy efficiency
3. Growing instability in fossil fuel supply and prices
4. Growing support to RE from governments and investors
5. Electricity generation by new and different entities[6]

These trends create uncertainty in the sector, forcing regulators, grid operators, planners, and electric utilities to contend with technology changes evolving at a rapid pace, while also balancing the conventional, pre-existing pressures to increase electricity access, increase the amount and reliability of the electricity provided, and improve the quality of services rendered.

Over the past few years, India has set itself ambitious targets for expanding its RE capacity, which has led to dynamic changes in the energy ecosystem in India comprising utilities, RE producers, and electricity consumers. This has also led to its own share of challenges, some of which we have played out in recent times. The current state of play in the energy sector and the resultant challenges are discussed next.

Status Quo and Indicators

Current RE Capacity

As of December 31, 2019, India had a total installed RE capacity of approximately 86 GW.[7] Of this, solar energy capacity was close to 34 GW (39%) and wind energy capacity was about 37 GW (about 44%).[8] In 2019, about 7.5 GW of new utility-scale solar capacity and about 1 GW of rooftop solar capacity were added to India's solar capacity.[9] The states at the forefront of solar capacity expansion were Karnataka (2 GW), Rajasthan (1.7 GW), Tamil Nadu (1.5 GW), Gujarat (936 MW), Andhra Pradesh (917 MW), and Madhya Pradesh

---

1 India's Intended Nationally Determined Contribution: Working Towards Climate Justice. Details available at https://www4.unfccc.int/sites/submissions/INDC/Published%20Documents/India/1/INDIA%20INDC%20TO%20UNFCCC.pdf; Niti Aayog. 2015. Report of the Expert Group on 175 GW RE by 2022. Details available at http://niti.gov.in/writereaddata/files/writereaddata/files/document_publication/report-175-GW-RE.pdf

2 Status of the Paris Agreement, United Nations Treaty Collection. Details available at https://treaties.un.org/Pages/ViewDetails.aspx?src=TREATY&mtdsg_no=XXVII-7-d&chapter=27&clang=_en

3 Article 2 of Paris Agreement, UNFCCC. Details available at https://unfccc.int/files/meetings/paris_nov_2015/application/pdf/paris_agreement_english_.pdf

4 India's Intended Nationally Determined Contribution: Working Towards Climate Justice. Details available at https://www4.unfccc.int/sites/submissions/INDC/Published%20Documents/India/1/INDIA%20INDC%20TO%20UNFCCC.pdf

5 Jairaj, B., S. Martin, J. Ryor, *et al*. 2016. The Future Electricity Grid: Key Questions and Considerations for Developing Countries. World Resources Institute. Details available at https://www.wri.org/publication/future-electricity-grid

6 Ibid.

7 CEA Monthly Report (December 2019). Details available at http://cea.nic.in/reports/monthly/installedcapacity/2019/installed_capacity-12.pdf

8 CEA Monthly Report (December 2019). Details available at http://cea.nic.in/reports/monthly/installedcapacity/2019/installed_capacity-12.pdf

9 India installs 7.5 GW of utility-scale solar and 2.4 GW of wind in CY2019. JMK Research and Analysis, January 17, 2020. Details available at https://jmkresearch.com/india-installs-7-5-gw-of-utility-scale-solar-and-2-4-gw-of-wind-in-cy2019/

(651 MW).[10] The total installed wind energy capacity increased by 2.4 GW in 2019, with Gujarat (1.4 GW), Tamil Nadu (650 MW), and Maharashtra (212 MW) being the leading states in wind energy.[11]

It is unsurprising that these states are leading the RE capacity additions in India, since south and west India have more RE potential – particularly solar PV and wind energy. Other states are still at early stages of developing their renewable energy capacity. This is important to consider as India seeks to add more RE capacity in the coming months and years. The question, therefore, is how much more RE capacity can the southern and western Indian states absorb versus how much RE capacity will other states need to add? The national RE targets must be broken down into the specific contexts of different states based on their varied needs and constraints.

Slowdown in the RE Tendering Process

India's RE growth in the year 2019 was at the slowest pace in the past 4 years.[12] There were several reasons for this, including the trends seen during the process of auctioning RE capacity. During the process of reverse auctions, when the auctioning agency sets an upper limit in the tariff for the project bid, developers are constrained to bid lower than the cap imposed on the tariff.[13] As per one study, auctions worth 8.4 GW were under-subscribed by 4.4 GW in 2019, and this under-subscription was attributed to applicable caps on tariffs.[14] On the one hand, tariff caps make the investment unattractive for the developer, and on the other hand, the resultant fall in the quantum of tendered RE capacity has an adverse impact on the overall RE capacity added in a year. It has been reported that the Ministry of New and Renewable Energy (MNRE) is contemplating a removal of such tariff caps, though there has not yet been any official announcement on this.[15]

Achieving the 2022 Target

The target of 175 GW has a deadline of the year 2022, which was recently clarified to be December 2022.[16] Union Minister R K Singh has repeatedly expressed confidence that the target of 175 GW of the installed renewable energy capacity will be met by the year 2022 as planned.[17]

This statement is contrary to the projections by CRISIL, which estimates that India may have installed capacity of only about 104 GW by 2022, 42% short

[10] Ibid.

[11] Ibid.

[12] Joshi, A. and B. Abdi. 2020. India's renewable energy generation registers lowest growth in 4 years. *ETEnergyworld*, January 17. Details available at https://energy.economictimes.indiatimes.com/news/renewable/indias-renewable-energy-generation-registers-lowest-growth-in-4-years/73327393

[13] Priya Sanjay. 2020. MNRE mulls removal of tariff caps for solar and wind tenders. MERCOM India, February 11. Details available at https://mercomindia.com/mnre-mulls-removal-tariff-caps-solar-wind/

[14] Ibid.

[15] Ibid.

[16] Ministry of New and Renewable Energy, Clarification 4/9/2019-EFM dated October 3, 2019. Details available at https://mnre.gov.in/sites/default/files/webform/notices/Clarification.pdf

[17] India on track to achieve 175 GW of renewable energy by 2022: Government, Economic Times (October 16, 2019). Details available at https://economictimes.indiatimes.com/small-biz/productline/power-generation/india-on-track-to-achieve-175-gw-of-renewable-energy-by-2022-government/articleshow/71614562.cms

of the government's target of 175 GW.[18] It has also been estimated that India will need about $330 billion in investments in the course of the next decade to meet its renewable energy goals.[19]

However, the Government of India remains confident that the 175 GW will be achieved by 2022. A statement by the Secretary, MNRE recorded in a recent Lok Sabha Standing Committee Report[20] reflected optimism about not just achieving, but exceeding the target of 175 GW by 2022. This optimism is based on the roughly 31,000 MW under implementation and an additional 39,000 MW likely to be bid soon. Whether India will reach 175 GW as on December 2022 or not, there is no taking away from India's commitment to a significant non-fossil fuel-based energy future.

Challenges

Renewable Purchase Obligations as a Ceiling, Not Floor

One of the mechanisms for promoting the installation of RE capacity in India has been the stipulation of targets for a mandatory minimum purchase of a certain percentage of RE by utilities, which is known as a Renewable Purchase Obligation (RPO).[21] While most states have struggled to reach their RPOs, Karnataka, a leading RE state, has been asked by its regulator to curtail further procurement of solar energy from large-scale projects.[22] The

[18] REturn to uncertainty, CRISIL (October 06, 2019). Details available at https://www.crisil.com/en/home/our-analysis/reports/2019/10/return-to-uncertainty.html

[19] Can India realize its ambitious renewable energy targets? Details available at https://www.dw.com/en/can-india-realize-its-ambitious-renewable-energy-targets/a-51085629

[20] "[W]e have set a target of 175 GW of installing Renewable Energy capacity by 2022 in 2015. In 2015, that looked very ambitious. Out of 175 GW, 82,580 MW have already been established and 31,000 MW is under implementation. Other than this, 39,000 MW is under bidding. If we add all these capacitities (sic) which is under implementation and underbidding and already implemented, so we reach a figure of 152.85 GW. So, with another 23 GW left, we are confident that by 2022, we would not only achieve the target but we would exceed the target." Details available at http://164.100.47.193/lsscommittee/Energy/17_Energy_1.pdf

[21] See Section 86(1)(e) of the Electricity Act, 2003 and Clause 6.4(i) of the National Tariff Policy, 2016

[22] Thomas, T. 2019. Karnataka puts a stop on new solar energy projects. *LiveMint*, May 02. Details available at https://www.livemint.com/industry/energy/karnataka-puts-a-stop-on-new-solar-energy-projects-1556771536456.html

RPO, which was meant to be a floor (minimum), is thus also being used as a ceiling (maximum). The decision to restrict RE procurement rather than enhance or exceed the RPO benchmarks has not sent out a positive signal for the growth of the RE sector in India's leading RE state.

The potential for RE capacity in India is not uniform across states. The southern states have shown themselves to be leaders in RE. In light of India's 2030 target of 40% of electricity capacity to come from non-fossil fuel sources, it is necessary that each state should try to reach this target on an individual level. RE-rich states such as Karnataka and Tamil Nadu will need to exceed the "average" given that states geographically located in areas with less RE capacity may not be able to achieve their individual targets. Aspiring for lower RPOs instead indicates that practical and financial difficulties continue to pose obstacles even for the RE-rich states.

Finance for the RE Sector is Not Easy

As per the PRAAPTI Portal, electricity distribution companies (DISCOMs) owed a total of ₹82,073 crore as outstanding amounts at the end of October 2019 to various generators, including RE generators.[23] When DISCOMs face cash flow issues, this results in RE producers also facing a liquidity crisis. Public sector banks are hesitant to grant loans to RE projects, and not many private sector banks are forthcoming with loans.[24] Additionally, the interest rate of existing loans to RE companies has also witnessed a rise in recent months.[25] Industry specialists also point to the difficulties of raising funds from Centre-owned financial institutions, such as the Indian Renewable Energy Development Agency Limited (IREDA) and the Power Finance Corporation (PFC), as well as the challenges of accessing foreign funds.[26]

Policy Uncertainty is Bad for the Economy

The section on legal systems and contract enforcement in the Economic Survey 2018–2019 emphasized the importance of policy certainty for the enforcement of contracts and for the rule of law.[27] The value of the certainty of contracts and the importance of consistency and stability in rules and policy cannot be overstated in the energy sector in India. Some events in 2019 (discussed below) have shown how investor confidence can be adversely impacted when contracts and agreements are unilaterally altered.

When the possibility of the state reneging on or unilaterally changing the terms of a contract exists, it leads to an adverse impact on investor confidence as well as incurs additional costs (e.g., to pay unforeseen surcharges as well as costs for pursuing legal remedies), which had not been previously anticipated. Further, since pursuing legal remedies requires time, business must proceed in uncertain circumstances. Performing contracts in uncertain circumstances also hinders future planning of the businesses.

Karnataka

In 2019, the Karnataka Electricity Regulatory Commission (KERC) took the decision to retrospectively levy a five-fold increase in wheeling and transmission charges on open access consumers in the state.[28] Although the direction was ultimately set aside by the Karnataka High Court on the ground that KERC could not unilaterally alter the executed contracts,[29] it sent out a negative signal to the industry, in addition to the expending of substantial legal costs by the parties to the litigation.

Andhra Pradesh

In 2019, Andhra Pradesh's decision to review all power purchase agreements (PPAs) with RE producers was another development that raised concerns.[30] Protracted litigation in the state over tariff renegotiation also led to delays in payments by RE companies to their banks, mounting DISCOM debts, and an overall concern about RE investments in the state.[31] After months of uncertainty, the Andhra Pradesh Electricity Regulatory Commission (APERC) in

---

23 Payment ratification and analysis in power procurement for bringing transparency in invoicing of generators (PRAAPTI). Details available at https://praapti.in/

24 Seetharaman, G. 2019. Why India may not achieve its 2022 clean energy target. *Economic Times*, November 03. Details available at https://economictimes.indiatimes.com/industry/energy/power/why-india-may-not-achieve-its-2022-clean-energy-target/articleshow/71869684.cms?from=mdr

25 Ibid.

26 Singh, M. 2020. Solar power: in a slump India's booming. *Down To Earth*, January 07. Details available at https://www.downtoearth.org.in/news/energy/solar-power-in-a-slump-india-s-booming-68445

27 "The economic model described in the blueprint is explicitly about creating virtuous cycles in an evolving, complex landscape. It is about investment, risk-taking and innovation in an environment that is inherently uncertain and unpredictable due to a range of factors from changing technology and consumer preferences to geopolitics and economic cycles…" Source: Shifting gears: private investment as the key driver of growth, jobs, exports and demand', Chapter 1. Details available at https://www.indiabudget.gov.in/budget2019-20/economicsurvey/doc/vol1chapter/echap01_vol1.pdf

28 Saumy Prateek. 2019. Karnataka court quashes KERC order increasing wheeling charges for open access power, MERCOM India, March 20. Details available at https://mercomindia.com/karnataka-court-order-wheeling-open-access/

29 Ibid.

30 Singh, K. 2019. A timeline: the Mexican standoff in Andhra Pradesh, India's renewable energy badland. *Quartz India*, November 25. Details available at https://qz.com/india/1755170/timeline-of-andhra-pradeshs-standoff-with-renewable-developers/

31 Policy flip-flops will have renewable energy target missing by over 42%: Report. *Economic Times*, October 06, 2019. Details available at https://economictimes.indiatimes.com/industry/energy/power/policy-flip-flops-will-have-renewable-energy-target-missing-by-over-42-report/articleshow/71465557.cms

February 2020 directed the state utilities to procure power from RE producers to meet the state's energy needs and to honour the power purchase agreements that it had entered into, pending a final judicial decision on the ongoing dispute.[32]

This kind of policy uncertainty is bad for the economy. As the Economic Survey rightly notes, "This is a world of 'butterfly effects' and unintended consequences, where uncertainty is inevitable. As uncertainty exacerbates, the temptation to renege on contracts when the ex post outcome is different from the one expected ex ante, the ability to enforce contracts and the rule of law become critical to navigating an uncertain world…"[33] Along with low tariff margins and tariff pressure, policy uncertainty in the form of retrospectively cancelling net metering and the failure to honour capital incentives have made it difficult for RE companies, particularly smaller RE companies, to survive.[34]

Similar concerns have been raised by RE companies over the uncertainty over import duties, particularly for solar cells. While the aim of the increase in import duties is purportedly to promote domestic manufacturing, the impact will be faced by solar energy companies in terms of higher costs.[35] As India takes its next step towards a clean energy future, these challenges will need to be overcome.

Suggestions for Improving Sector Governance

Improve Data Collation and Sharing

In order to address these challenges and policy uncertainty in the electricity sector in India, the need for better and more reliable data is paramount. The energy sector in India encompasses a variety of institutions and bodies, with most of them having the power to collect data under different legislations.[36] These should be harnessed in order to collect and make available relevant data on energy usage. Data on consumption by different sectors (industry, agriculture, households, etc.), captive power plants, open access energy procurement, and so on will be particularly useful in order to fill policy gaps and frame new regulations.

The organization and dissemination of data must be treated as a priority area by state agencies that have access to such data and the power to collect data.[37] In practice, since it is predominantly the CEA that has the mandate to disseminate data, a heavy burden is placed on it to perform this function, a problem that is complicated due to its inadequate human resources and technical capacity, limiting its ability to perform such a function.[38]

Since India straddles the challenges of improving energy access and increasing RE on the grid, its energy profile continues to evolve. The challenges thrown up by this transition are also multifaceted and by no means stagnant. The data needs may span several metrics. For example, the data provided by the Saubhagya dashboard focuses on the number of households electrified.[39] Yet, data on the quality and reliability of the supply of electricity (including the actual number of hours of supply) and the number of households disconnected due to defaults of payments after the provision of the initial connection are absent.[40]

Additionally, we require better and more nuanced data on the demand and consumption of electricity in order to formulate analysis on India's future energy requirements. Since many of the electricity connections serving rural households and agricultural consumers are unmetered, we do not know accurately how much energy is required for these consumers and how much is being consumed.[41] Linking this back to India's RE targets, the MNRE has set a target of 25,750 MW of solar energy through the Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan (PM KUSUM) scheme and 18,000 MW under the new Solar Rooftop scheme by 2022. Improving the manner in which the data is collected and shared in the

[32] AP power regulator snubs discoms over renewable energy obligations. *Business Standard*, February 10, 2020. Details available at https://www.business-standard.com/article/economy-policy/ap-power-regulator-snubs-discoms-over-renewable-energy-obligations-120021001385_1.html

[33] Chapter 01: Shifting gears: private investment as the key driver of growth, jobs, exports and demand. *Economic Survey* (2018-2019)

[34] Srivastava, V. 2019. Rooftop solar players shut shop as going gets tough. *Financial Express*, July 19. Details available at https://www.financialexpress.com/industry/indian-epc-rooftop-solar-players-shut-shop-as-going-gets-tougher-on-financial-woes/1646455/

[35] Utpal Bhaskar. 2020. Energy firms cry foul over hike in customs duty on solar equipment. *LiveMint*, February 3. Details available at https://www.livemint.com/news/india/energy-firms-cry-foul-over-hike-in-customs-duty-on-solar-equipment-11580693910254.html

[36] See Section 3, An assessment of energy data management in India. Prayas (Energy Group), October 2014. Details available at http://www.prayaspune.org/peg/publications/item/download/553_bef093ce2d7be5d2cfbe6351f4ea2fe1.html

[37] See Section 3, An assessment of energy data management in India. Details available at http://www.prayaspune.org/peg/publications/item/download/553_bef093ce2d7be5d2cfbe6351f4ea2fe1.html

[38] Supra note 33

[39] Details available at https://saubhagya.gov.in/

[40] Sreekumar, N., M. Mandal, and A. Josey. 2019. 100% rural electrification is not enough. *Hindu Business Line*, March 26. Details available at https://www.thehindubusinessline.com/opinion/100-rural-electrification-is-not-enough/article26645721.ece#

[41] Tripathi, B. 2019. Why is India unable to provide 24x7 electricity despite building more power stations? Scroll, June 23. Details available at https://scroll.in/article/927361/why-is-india-unable-to-provide-24x7-electricity-despite-building-more-power-stations

public domain will help us identify and overcome barriers and track progress.

Further, in order to improve the accessibility and dissemination of data, it has been suggested that the data should be made available in easy-to-use formats such as .xls and .csv.[42] Further, workshops among various data agencies to harmonize and reconcile the collected data and exchange ideas on best practices are also recommended.[43]

Improve Centre–State and State–State Coordination

As mentioned above, the Central Government has laid down certain national goals in the field of energy, including in pursuance of its obligations under the Paris Agreement. It is not always clear how these national goals can be further broken down into achievable targets for individual states. A recent development is the announcement of a Renewable Energy Promotion and Facilitation Board, with the intention of minimizing risks for developers in the RE sector. It may be a good initiative in this regard.[44] The Board seeks to act as a liaison between developers and various state governments and authorities and to coordinate actions with various financial institutions. Though it is yet to be established, the Board can indeed play a significant role in helping states tackle specific barriers and roadblocks to RE implementation.[45]

In addition, there is much that can be achieved through more sharing between states. As emphasized above, the RE capacity of India's states have varied potential and are at different stages of development. Instances such as Karnataka's pushback against the extant RPOs indicate that even states with sizeable RE potential may not have adequate incentives to expand their RE capacity beyond a certain threshold. At the same time, other states with lower natural potential for renewable energy and at a less advanced stage of capacity development may not be able to meet the goal of enhancing their RE procurement.

For example, mechanisms to allow RE-rich states to sell their RE to other states may be worth exploring. Rajasthan's Solar Energy Policy 2019 introduced a cess of ₹2.5 lakh per MW per year for selling solar power within the state and ₹5 lakh per MW per year for selling power outside the state.[46] Although, in principle, the power is being sold to other states at a premium,

---

42 *Supra* note 33

43 Supra note 33

44 Singh, S. C. and S. Mohanty. 2000. Centre to set up renewable energy board to cut developers' risks. *Economic Times*, February 19. Details available at https://economictimes.indiatimes.com/industry/energy/power/centre-to-set-up-renewable-energy-board-to-cut-developers-risks/articleshow/74200983.cms?

45 Ibid.

46 Shreya Jai 2019. Rajasthan levies ₹2-5 lakh cess on solar projects, registration fee up 5x. *Business Standard*, December 10. Details available at https://www.business-standard.com/article/economy-policy/rajasthan-levies-rs-2-5-lakh-cess-on-solar-projects-registration-fee-up-5x-119121000504_1.html

selling solar power to other states can help them meet their RPOs while at the same time compensating Rajasthan for the utilization of its energy infrastructure in the form of land and wires.[47]

Done right, RE can provide multiple development benefits: the creation of jobs,[48] reductions in local air pollution, enhanced livelihoods, more inclusive decision-making, energy security, employment, economic growth, and so on. The sharing of lessons between states will help create a larger pool of policy and regulatory interventions to choose from.

Improving Transparency, Accountability, and Participation in the Sector

India's energy transition efforts have focused on creating enabling environments for investors and RE developers and not necessarily on building institutional capacity, developing robust stakeholder processes, or enhancing sector transparency. As India considers the next steps in the energy transition, there is an urgent need to reinfuse these processes with public interest by seeking the opening up of these processes to a wider range of voices and drawing greater attention to issues such as affordability, service quality, and environmental impacts. Another acknowledged challenge in the electricity sector is the limited capacity in key government and regulatory agencies, particularly at the subnational level.

Many of the issues discussed above highlight governance challenges in the sector. In addition to ensuring 24x7 electricity for all and increasing the contribution of clean and renewable energy in the energy mix, sector decision-makers need to ensure financial viability of the sector while making decisions about investment priorities, resource mix, and pricing of electricity. The workings of these institutions—policymaking, planning, and regulatory—are often complex, and opening the decision-making processes in these institutions to a broader set of stakeholders could reduce the inefficiencies, short-term gains, and suboptimal decisions that often result.

On the demand side, there are an increasing number of electricity consumers who want to be part of the clean energy transition that includes local renewable energy generation in combination with energy conservation and efficiency measures. The success of India's residential rooftop solar programme will, in part, depend on how decision-makers engage with consumers.[49] Some of the examples discussed above demonstrate that important decisions in the energy sector could benefit from more participation and support from a wider set of stakeholders.

Conclusion

Even though India's energy goals are predominantly defined at the national level, its energy transition will take place differently in different states. Some states face greater capacity challenges to adopt and implement the national level clean energy and energy access commitments than others. In addition to capacity challenges, technical challenges remain with integration of renewables in the grid – changes in consumer behaviour, electricity generation ownership patterns, and institutional arrangements raise questions on consumer tariff design and utility revenue models. Regulators and policymakers will need to find the right balance between stability and flexibility in this era of declining costs of renewables and improved performance of new technologies. Additionally, the policymaking for the future should have greater robustness and certainty in order to boost investor confidence.

In conclusion, there is no doubt that ambitious RE and climate targets have pushed India well on its way to a clean energy future. However, more needs to be done to help India achieve its potential. As this article discusses, some of these efforts are technical and financial, while others will need focused efforts to improve the governance of the sector. EF

Parul Kumar and Bharath Jairaj work with the Energy Programme of the World Resources Institute India.

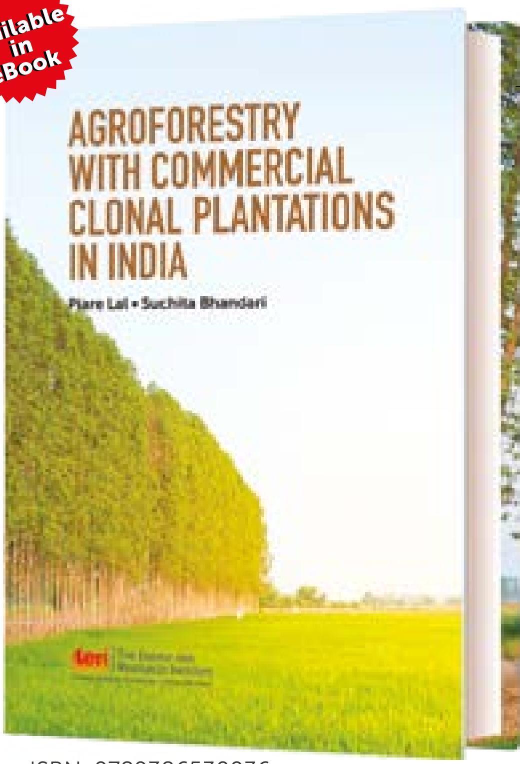
47 Srivastava, V. 2019. Rajasthan revises developer contribution in solar policy. *Financial Express*, December 24. Details available at https://www.financialexpress.com/economy/rajasthan-revises-developer-contribution-in-solar-policy/1802571/

48 Jairaj, B., P. Deka, and S. Boehm. 2017. India's renewable energy push: a win-win for job creation and electricity access. World Resources Institute Blog. Details available at https://www.wri.org/blog/2017/11/indias-renewable-energy-push-win-win-job-creation-and-energy-access

49 Devi, A., U. Narayan, and T. Mandal. 2018. Here comes the sun: residential consumers' experience with solar rooftop in five Indian cities. World Resources Institute. Details available at https://www.wri.org/publication/here-comes-the-sun

A COMPREHENSIVE GUIDE TO UTILIZATION OF SCIENTIFICALLY PROVEN TOOLS AND TECHNIQUES FOR CLONAL PROPAGATION OF TREES AND THEIR ROLE IN AGROFORESTRY DEVELOPMENT AND REFORESTATION PROJECTS

Available in eBook



Major topics covered

- Status of Forest Resources in India
- Soils and Management of Soil Fertility
- Basic Concepts of Forest Genetics and Tree Improvement
- Modern Clonal Plant Production Nurseries
- High Yielding Clonal Plantations: Poplars, Eucalyptus, and Casuarina
- Improving Productivity of Clonal Plantations
- Research and Development Priorities
- Understanding Extension
- Holistic Development of Agroforestry in India

• ISBN: 9789386530936
• Subscription Price: ₹650 • Perpetual Price: On request

Rapid deforestation and depletion of genetic resources have made it essential that avenues be found whereby genetically improved planting stock of short-duration trees can be mass produced. The clonal agroforestry plantations provide sustainable alternative to the use of natural forests.

Agroforestry with Commercial Clonal Plantations in India provides complete scientific information on clonal technology applications for selection and cloning of candidate plus trees, development, field testing final selection and large-scale deployment of genetically superior, high yielding and fast-growing clones of important tree species in agroforestry and reforestation projects.

The Energy and Resources Institute
Attn: TERI Press
Darbari Seth Block
IHC Complex, Lodhi Road
New Delhi – 110 003/India

Tel. 2468 2100 or 4150 4900
Fax: 2468 2144 or 2468 2145
India +91 • Delhi (0)11
Email: teripress@teri.res.in
Web: http://bookstore.teri.res.in

To purchase the book, visit our online bookstore at http://bookstore.teri.res.in or send us your demand draft or cheque in favour of TERI, payable at New Delhi (outstation cheques are not accepted).

GREEN STEEL FOR A GREEN ECONOMY

The 'harder to abate' sectors – a categorization that includes the iron and steel sector – account for around 40% of the total carbon dioxide emissions from today's energy system, and these emissions will increase as emerging economies continue to develop unless steps are taken to promote 'green steel'. In this article, **Will Hall**, **Thomas Spencer**, and **Sachin Kumar** discuss short- and long-term actions for the iron and steel sector, covering the technological solutions and possible policy options that could help drive a sustainable transition.

As with all economies, steel is a material of vital importance to the Indian economy. If the living standards of Indian citizens are to increase, the use of steel will also need to increase substantially. With this increase in steel demand comes a myriad of challenges and opportunities, not the least amongst them being the impact this would have on the environment.

At TERI, we have developed a robust understanding of the factors that drive the transition towards cleaner technologies through our Energy Transitions Commission India work programme. Whilst much work has been carried out in the power sector, we are just beginning to understand what such a transition might look like for the highest energy consuming sectors of the Indian economy, that is, the heavy industry sectors, chief amongst them being steel.

In January 2020, we published a report[1] presenting an initial overview of the Indian steel sector and the options to mitigate its impact on the environment through reducing emissions. This report clearly shows that more can be done in the near term to mitigate emissions from the steel sector, including driving forward with cost-effective energy efficiency measures and maximizing the efficient use of resources. India will also need to start exploring deep decarbonization alternatives, including hydrogen, electrification, and carbon capture, use and storage (CCUS). India is set to be a major beneficiary from advancements in these key technologies and should be proactive in pushing ahead with collaborative projects and pilot plants. This article will set out the lessons we learned from undertaking this work, covering steel demand, production technologies, and policy measures.

Importance of Steel in the Development of the Indian Economy and the Welfare of Its Citizens

Steel is the foundation of a developed economy. It supports the infrastructure that facilitates growth, the housing that drives urbanization, and the machinery and tools that power industrialization. No country has achieved high levels of income per capita without substantially raising steel consumption per capita. At only about 64 kg/year, India's steel consumption per capita is still very low, consistent with India's low GDP per capita. This is only 27% of the world average, a clear indication that large steel consumption growth is required to raise India's GDP per capita and improve the welfare of its citizens.[2]

As India's Economy Grows, Its Steel Demand Will Grow Substantially

India's GDP per capita, even when measured at purchasing power parity (PPP), is only around 6900 USD, just 43% of the world's average. A significant portion of the population still lives below the poverty line. As of 2011, the year of the last Census, 20% of the population lived below the minimum international poverty benchmark of 1.90 USD per day of consumption expenditure. Clearly, India must grow its economy in order to have higher income per capita and improved welfare for its citizens. This raises the question of the impact of India's economic growth on its steel demand. We have made projections for the Indian economy out to 2050 and derived projections for India's steel demand from these economic scenarios. In our baseline scenario, India's GDP per capita grows from the current level to about 25,000 USD by 2050, measured in constant 2011 PPP. This is an ambitious but feasible long-term growth scenario that would lead India into the ranks of high-income countries. In this baseline scenario, India's steel demand grows by more than a factor of 5 between now and 2050 – from about 94 to 489 Mt (million tonnes). We do not project India's steel demand to saturate by 2050, but it would instead continue to grow beyond this point.

[1] Hall, W, T. Spencer, and S. Kumar. 2020. Towards a Low Carbon Steel Sector: Overview of the Changing Market, Technology, and Policy Context for Indian Steel. New Delhi: The Energy and Resources Institute (TERI)

[2] The above figures are based on data from the World Steel Association and take true steel consumption per capita as the metric. The figure quoted for the world is the value for a panel of 74 countries for which the World Steel Association provides data on true steel consumption per capita.

Substantial Uncertainty in These Projections, Even Before Considering More Disruptive Factors

There is considerable uncertainty in projecting both the Indian economy and the steel demand out to 2050. Both the rate of economic growth and its key drivers are uncertain. Will India follow a more service-based economy or will its rate of infrastructure investment and industrialization pick up, following a path more similar to that charted by China and other East Asian industrial powerhouses, such as Taiwan and South Korea? In our analysis of the historical experiences of a large number of countries, we find that the most significant determinants of steel demand are the rate of investment and industrialization in the economy, not the absolute level of GDP per capita.

In order to analyse the full range of possible pathways for Indian steel demand, we constructed sensitivities on our baseline economic scenario out to 2050. In the high scenario, the rate of investment, industrialization, and overall growth are higher than in our baseline scenario, consistent with a 'Make in India' style development scenario. In the low scenario, investment, industrialization, and aggregate growth are lower than in the baseline scenario, consistent with a more service led and potentially more unequal development trajectory.

These different economic scenarios have a huge impact on our projection of Indian steel demand out to 2050. The high scenario sees steel demand to become almost 40% higher than in the baseline scenario (at 755 Mt by 2050), which is close to, but still below, China's level of steel demand in 2017. In the low scenario, steel consumption is almost 40% lower than the baseline scenario (at 289 Mt by 2050). We have used the baseline scenario as our central scenario. However, the large spread between high and low scenarios indicates a wide band of possible outcomes, dependent on the development trajectory of the Indian economy. Figure 1 shows the results of these scenarios.

Level of Steel Demand Growth Projected in the Baseline to Have Significant Economic and Environmental Externalities

Although the iron and steel sector is critical for economic growth, it is energy and resource intensive. Rapid growth of Indian steel demand can have significant environmental and economic consequences. The iron and steel sector is already the largest industrial sector in terms of energy consumption. In addition, it accounts for a significant share of India's manufacturing goods trade deficit (i.e., about 7.4%) if we include the net import of coking coal and iron and steel products.

In our baseline scenario, energy demand from the iron and steel sector by 2050 would grow by a factor of 4, from about 59 Mtoe (million tonnes of oil equivalent) in 2016 to about 235 Mtoe. This is substantially slower than the growth in the total steel demand (a factor 5 increase), indicating that we expect substantial improvements in energy efficiency to occur even in our baseline scenario. Coking coal requirements could grow from 60 to 218 Mt, implying an increase in the import bill from 10 billion USD today to 33–40 billion USD by 2050. Emissions of CO_2 would grow from today's level of 242 Mt to about 837 Mt by 2050 in our baseline scenario. This is equivalent to 35% of India's total current emissions of CO_2 from fossil fuel combustion and industry. The growth in emissions by a factor of 3.45 is lower than our projected growth of energy demand (factor 4), indicating that we consider some decarbonization of iron and steel production even in our baseline scenario. Clearly, this level of resource consumption, energy consumption, and GHG emissions is a concern. Incremental measures to improve energy and carbon efficiency in the iron and steel sector are not enough to place it on a trajectory consistent with limiting warming to less than 2°C.

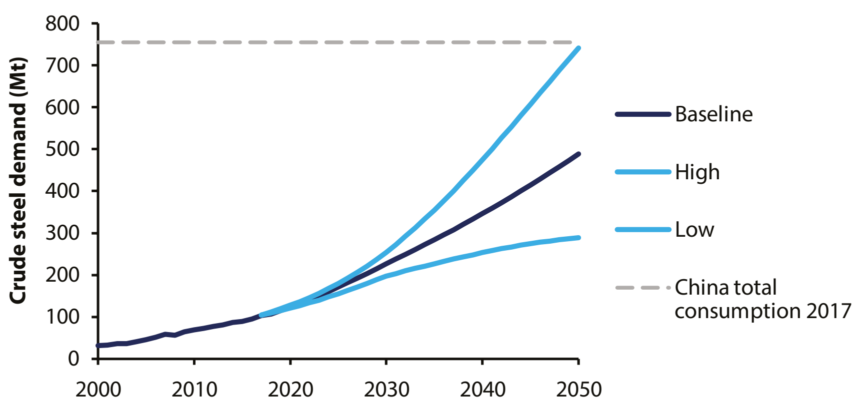


Figure 1 Range of projections for Indian steel demand out to 2050

Source *TERI modelling and analysis*

Iron and Steel Sector Can No Longer Be Excluded from International or Indian Climate Policy Focus

In 2015, the iron and steel sector accounted for about 6.2% of global emissions from fossil fuel combustion. If the sector were a country, it would be the fifth largest emitter after China, the United States, the European Union, and India. Despite its large emission footprint, the iron and steel sector has largely been exempted from stringent climate policy measures. It is economically significant and exposed

to international competition, and countries have long been concerned about the impact of unilateral measures on the domestic industry's international competitiveness. At the same time, coordinated international approaches have not been developed. In addition, the level of technical and commercial readiness of mitigation technologies has been lower in the iron and steel sector compared to other sectors like electricity production. Thus, policymakers and corporations have implemented strategies to incrementally improve energy efficiency, but shied away from more profound decarbonization of the iron and steel sector.

However, this cannot continue. By 2050, in scenarios consistent with limiting warming to less than 2°C, the carbon intensity of steel production needs to be reduced by at least 70% globally. In 2050, India will be one of the few world regions (alongside Africa) still expecting further growth in iron and steel demand. China's steel demand will have peaked (indeed may already have peaked) and will follow the trajectory of plateau and decline charted by developed countries before it.

Thus, in order for India's long-term development to be consistent with a global scenario of limiting warming to 2°C, it is essential that the world establishes a pathway towards zero carbon steel and that India transitions towards this pathway as well.

Strategies Towards Iron and Steel Sector Transition Need Not Be 'All or Nothing'

Because of large facilities, huge investments, and long plant lifetimes, it may seem that a pathway towards zero carbon steel is 'all or nothing'. If this were so, it is understandable that policymakers and business strategists would shy away from such a proposition, particularly when the decarbonization technology in the iron and steel sector is still far from commercially available. However, we argue that this is an incorrect framing. It is possible to envisage a feasible, cost-effective, and stepwise pathway for Indian iron and steel that would allow the sector to contribute to a global effort to limit warming to less than 2°C. We argue that this pathway is firmly in India's interest: it would innovate a much less resource, import, and energy intensive pattern of industrialization for India. The following sections outline the three key pillars of this pathway.

Pillar 1: Improve Energy Efficiency, Resource Efficiency, and Material Circularity

Owing to heavy reliance on coal-based direct reduction (DR) and the presence of many older, relatively inefficient blast furnace units, the Indian iron and steel sector is relatively energy intensive compared to international benchmarks. However, on reviewing a large number of possible energy efficiency measures, we have noted that the average plant could lower energy consumption per unit of output by 24–38% depending on the production route. This would have important benefits in lowering aggregate energy consumption and CO_2 emissions, where the adoption of best available energy efficiency technologies could reduce overall emissions by up to 15% by 2050 versus the *baseline* (where some energy efficiency measures continue to be introduced from today).

Reducing steel consumption through resource efficiency can have a substantial benefit in terms of more efficient aggregate resource use across the Indian economy. Indeed, certain structural trends such as the emergence of ride-sharing services (Uber/Ola), the emergence of the gig economy, teleworking, and coworking suggest that the future Indian economy, even in the absence of further policy measures, may in fact be less steel intensive than the baseline scenario presented above. If we also consider policies to actively promote resource efficiency, steel demand could be 25% lower by 2050 compared to our baseline scenario. Production of energy intensive primary steel can be avoided by increasing the collection and use of domestic scrap steel, which is 85% less emission intensive than primary steel today. In addition, India already imports substantial quantities of scrap and there may not be much scope for increasing scrap imports. In a low carbon future, demand for scrap in developed countries is likely to increase, given the reduced emissions through the secondary production route. A scenario combining resource efficiency and increased circularity could further reduce emissions by 20% by 2050.

Pillar 2: Implement Transition Strategies by the 2030s and Deep Decarbonization Options by the 2040s

Even with the above-described energy and resource efficiency measures, the iron and steel sector would still emit around 500 Mt of CO_2 by 2050. Theoretically, substituting natural gas for coal could further lower emissions, but this option can be discounted as a majority solution given the lack of domestic gas and the expense of imported gas in India. A more promising transition option would be the HIsarna

process, which can reduce emissions by 20% compared to the traditional blast furnace-basic oxygen furnace route (BF-BOF). If the resulting pure stream of CO_2 from the blast furnace route is captured using the carbon capture, use and storage (CCUS) route, emissions could be reduced by up to 80%. This technology is already being trialled in Europe by Tata Steel, the owner of the technology.

By the 2040s, it is expected that more radical decarbonization technologies, which are currently being demonstrated, would be commercially available. Of particular interest is the hydrogen route, which involves the substitution of coal or natural gas as a reducing agent with hydrogen. If hydrogen is produced from emission-free electricity, the total iron and steel emissions can be reduced by 94%. According to the analysis developed in our report, if hydrogen can be delivered at a cost of 2.5–3.5 USD/kg, the hydrogen route can be cost competitive with the BF-BOF route. This would require electrolyser costs to fall to around 400 USD/kW and renewable electricity to be priced in the range of 20–30 USD/MWh. Both assumptions are perfectly feasible by 2050 (renewable electricity is already in the range of 35 USD/MWh in India).

Assuming that new facilities after 2040 are based on the hydrogen route and hydrogen is increasingly blended in existing facilities to substitute coal, emissions can be reduced by further 8% by 2050. More importantly, the sector would be on a pathway to fully decarbonize thereafter. India would be the first ever country to industrialize while decarbonizing its steel production. The cumulative effects of these measures are shown in Figure 2.

Pillar 3: Promote International Collaboration, Innovation, and Technology Diffusion and Develop a Domestic Low Carbon Steel Strategy

India is faced with a paradox. Between now and 2050, it will be one of the major sources of growth of global steel demand. By 2050, India will be one of the few world regions whose steel demand will still be growing, even while the pressure to reduce global CO_2 emissions will only increase. It is thus in India's interest that global efforts to innovate a zero-carbon pathway for iron and steel succeed. In addition, Indian firms, notably Tata Steel, are active in the global market and own a number of key low carbon technologies. India does not have cost-effective reserves of natural gas or coking coal and so the development of a renewables plus hydrogen economy is in its interest. India should, therefore, actively promote international innovation, technology learning, and diffusion and become a major driver of the push to zero-carbon steel: it stands to be the major beneficiary.

India should develop a domestic pathway towards low emissions from the iron and steel sector by 2050 and zero emissions shortly thereafter, ideally by 2060. The long-term low emissions development strategy that India will submit to the UNFCCC provides an opportunity to do so, as does the India 2047 vision being developed by NITI Aayog. Domestic policy frameworks to promote energy and resource efficiency already exist in the form of the Perform, Achieve and Trade Scheme, the Steel Scrap Recycling Policy, and the Draft National Resource Efficiency

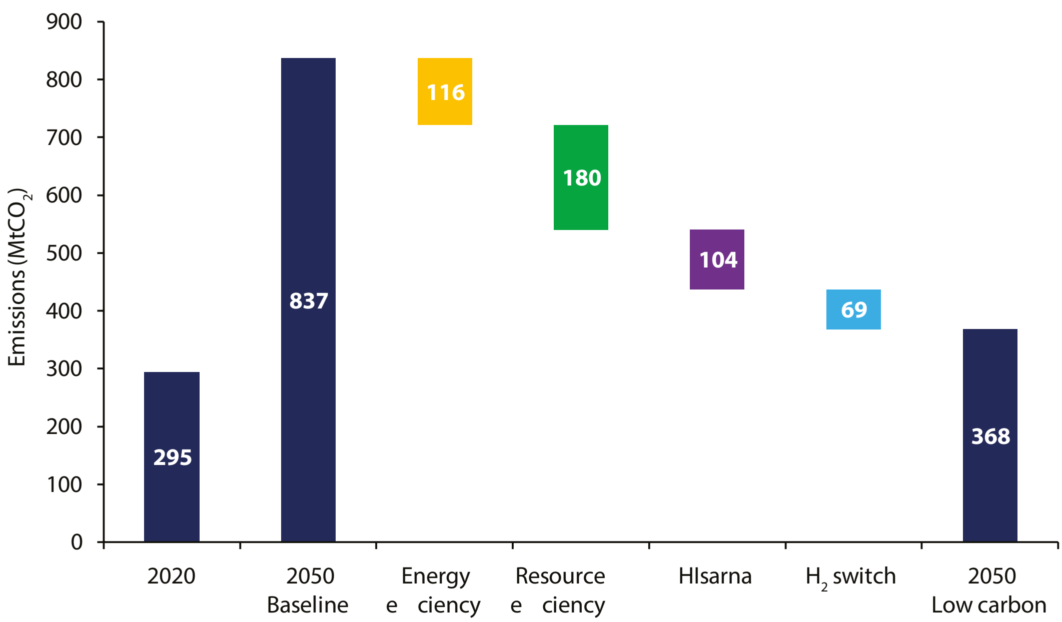


Figure 2 Cumulative impacts of the proposed measures

Source *TERI modelling and analysis*

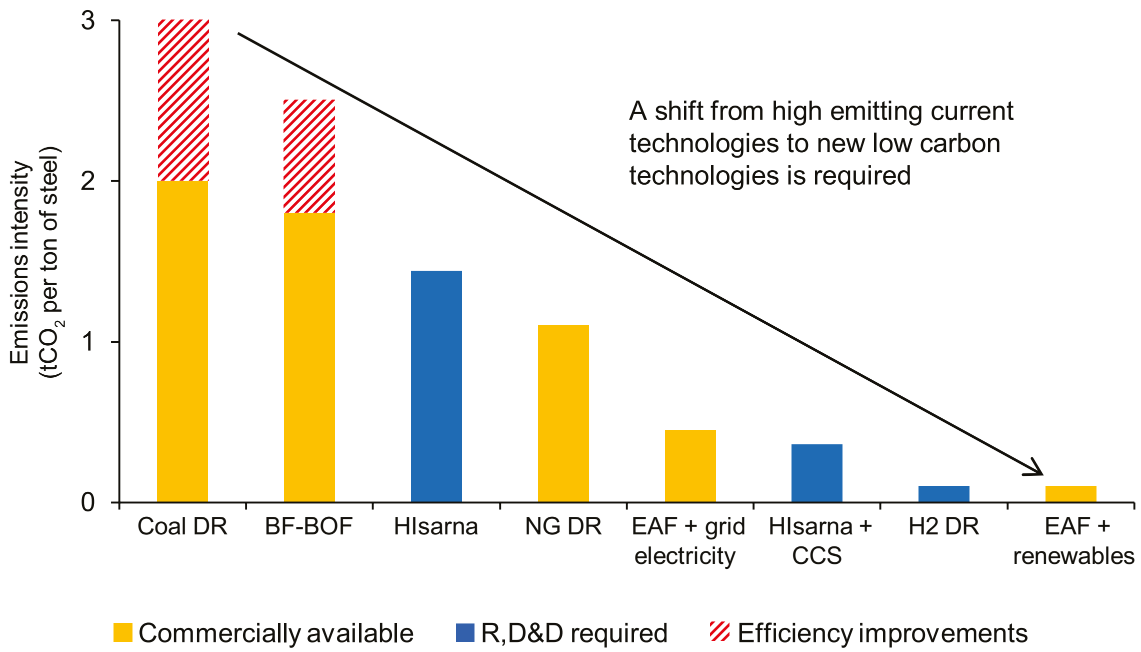


Figure 3 Emission intensity of steel production routes

Source TERI analysis based on Hall, W, T. Spencer, and S. Kumar. 2020. Towards a Low Carbon Steel Sector: Overview of the Changing Market, Technology, and Policy Context for Indian Steel. New Delhi: The Energy and Resources Institute (TERI) and ETC (Energy Transitions Commission). 2018. Mission Possible. Details available at http://www.energy-transitions.org/sites/default/ETC. DR – direct reduction, BF-BOF – blast furnace-basic oxygen furnace, EAF – electric arc furnace, CCS – carbon, capture and storage, H2 – hydrogen. 'Efficiency improvements' indicates difference between present-day Indian average and implementation of best available technologies.

Policy. These can be implemented and strengthened over time. They should also be complemented with policies to promote innovation and technology demonstration for crucial technologies such as HIsarna, CCUS, and hydrogen-based steel production (see Figure 3). This could include proactively pushing for international collaborative research, development and demonstration (RD&D) programmes, engaging in international consortia, and seeking funding and technology from international donors. In this regard, developed countries also need to realize that the climate policy agenda has to shift towards promoting industry decarbonization and supporting India in its endeavours to deploy low carbon technologies out to 2050.

Moreover, in combination with various supply-side policies, it will be important to complement these with measures to stimulate demand for low carbon steel. This can be in the form of buyers' clubs, whereby groups of businesses that use steel in their products (e.g., automotive manufacturers) agree to buy low carbon steel at a premium, so that they can then market their products as environmentally friendly alternatives. This can be supported by standard setting systems, such as the ResponsibleSteel™ standard. The government can also play an important role by buying large quantities of low carbon steel to help scale up production as has been done so effectively with LEDs under the UJALA scheme.

Finally, India should engage in the sensitive topic of international trade and potential measures to protect domestic industry in a world of uneven carbon prices and climate policy efforts. Carbon border adjustments are already being actively considered by the European Union and appear inevitable in a world of ever growing, but unevenly shared, concern about climate change. The iron and steel sector is likely to be the first to be targeted by such measures; Europe is one of India's major destinations for its steel exports. By engaging in global efforts to transition in the iron and steel sector, India can hedge against the risk of the imposition of climate-related trade measures.

Way Forward

Over the course of 2020, TERI will build on the work laid out in this article, engaging with the steel industry to develop a comprehensive action plan or 'roadmap' for emission reduction. This will provide a clear outline of the actions that need to be taken in the short, medium, and long term to put the steel sector on a pathway towards low carbon. EF

Will Hall is Associate Fellow, TERI; Thomas Spencer is Fellow, TERI; and Sachin Kumar is Senior Fellow, TERI.

A NEW APPROACH OF SMALL HYDRO POWER

Hydrokinetic Technology

Hydrokinetic energy is a promising source of renewable energy whose effective utilization has implications for rural electrification of remote areas, as well as in utilizing irrigation canals for energy generation. In this article, **Sunil Kumar Singal** and **Manoj Sood** provide an overview of hydrokinetic technology, the factors impacting their adoption, and their current challenges and opportunities.

The energy demand of a growing nation like India increases with increase in the pace of development. In order to fulfil increasing energy demand, the installation capacity needs to be enhanced. Thermal, nuclear, large hydro, and renewables (small hydropower, wind power, biopower, and solar power) are the various resources that can meet the energy demand. The installed capacity of India from these sources is shown in Figure 1, which shows that fossil fuel-based power stations are the major contributors to energy generation. However, energy generation using non-renewable sources has had catastrophic impacts on the environment. The consequences of burning of fossil fuels include acid rains due to sulphur dioxide, photochemical pollution due to nitrous oxide, and global warming due to the emission of CO_2 and other greenhouse gases (GHGs). Therefore, all over the world, governments are developing new strategies to enable their energy sectors to embrace renewable energy as well as to reduce the dependency on non-renewable energy sources. As a result of these new strategies, renewable plant capacity in India has increased from 24.9 to 82.58 GW in the past 8 years (Figure 1). Figure 1 highlights the following major points:

» The growth rate of non-renewable sources (thermal, nuclear) has reduced from 2016 onwards.
» Continuous and rapid growth in renewable sources (wind power, biopower, and solar power) can be seen from 2016 onwards.
» The hydropower sector has seen very

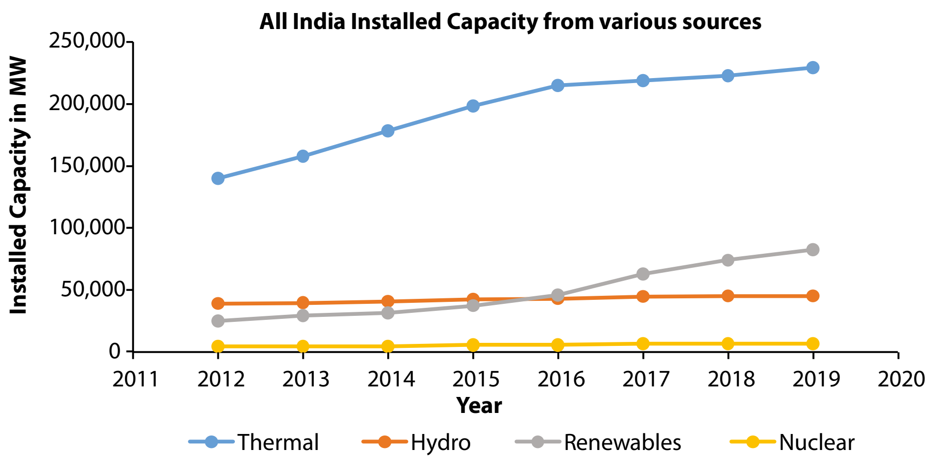


Figure 1 All India installed capacity in MW

slight growth (from 43.1 to 45.3 GW) during 2016–2019.

Submergence of land, emission of GHGs, alteration of the groundwater level, generation of downstream dry stretches, and the necessity for rehabilitation and resettlement of communities are some of the various reasons responsible for increased social and environmental awareness and reduced growth in the large hydropower sector. However, among the renewable energy sources, hydropower is the most promising, reliable, and predictable source of energy. Therefore, hydropower must be handled with such an outlook that the extraction ought to have the least effect on the environment and society.

In this context, the concept of small hydropower has been advanced as an arrangement to mitigate the adverse effects of large hydropower towards biodiversity, and small hydropower plants (SHPs) have become more prevalent. There is no universal concurrency over the definition of SHP as given in Table 1 and the definition is based on the introduced capacity.

Table 1 SHP definition for different countries

Country	SHP plant capacity (MW)
UK (NFFO)	<5
Sweden	<15
Colombia	<20
Australia	<20
India	<25
China	<25
United States	<30
Brazil	<30
Philippines	<50
New Zealand	<50

SHPs have various benefits over large hydropower plants, such as clean and renewable source, zero land submergence, eco-friendly, highly flexible, and minimal operational and maintenance costs. This hydro energy can be extracted by static method or kinetic method.

Static Method

In the static method, a hydro turbine converts water pressure into mechanical shaft power, which is used to drive an electric generator. The power available is proportional to the product of pressure head and volume flow rate of water. The power potential of hydro system is given by the following equation:

$$P = \eta \rho g Q H \quad (1)$$

Here, P is the rated output power in watt, g is the acceleration due to gravity in m/s^2, Q is the discharge passing through the turbine in m^3/s, H is the head of water in m, and η is the efficiency of the generating units comprising turbine and generator. SHP potential is available in high hills as well as in the plains. In hilly areas, the streams have steep gradients or vertical falls, thereby operating high heads in short stretches of the stream, whereas in the plains, the rivers have mild slopes. Run-of-river, canal based, and dam-toe are the different static-based schemes of small hydropower.

Kinetic Method

The kinetic method utilizes the kinetic head for the generation of energy. The velocity of flow (i.e., current of water) is utilized for rotating the blades of a turbine in order to convert the kinetic energy of water into mechanical energy. The governing equation of the hydrokinetic technology works on the similar principle of wind energy and can be represented as:

$$P = C_p \, 1/2 \, \rho A V^3 \quad (2)$$

Here, P is the available hydrokinetic energy in watt, is the density of water in kg/m^3, A is the turbine area in m^2, V is the velocity of the fluid in m/s and C_p is the power coefficient. This equation of hydrokinetic energy indicates the following four significant points:

1. Hydrokinetic power is dependent on the flow velocity and is independent of head.
2. The power extraction is directly proportional to the turbine area.
3. Power is directly proportional to the cube of velocity. If the velocity increases threefold, the power extraction will become 27 times.
4. The density also plays a major role. Since density of water is 1000 times higher than the density of air, it generates greater energy.

Advantages of Hydrokinetic Technology

Hydrokinetic technology eliminates all the major social and environmental issues related to large conventional hydropower plants.

1. **Diversion structure:** Hydrokinetic technology works on the natural pathway of river/man-made channels. Thus, it does not divert the water for the energy generation. Therefore, no diversion structure is required.
2. **Civil works:** The civil works required in hydrokinetic technology are minimal as compared to the conventional hydropower plants.
3. **Water head:** Hydrokinetic technology deals with kinetic head of water, that is, velocity head instead of potential head. Therefore, hydrokinetic turbines work on zero head, and thus no arrangement is required to create water head.
4. **Impact on the biodiversity:** Hydrokinetic technology neither stores water nor changes the natural pathway, and thus it does not affect the migration of fish from upstream to downstream and vice versa.
5. **Rehabilitation and resettlement of people:** Construction of large hydropower plants needs large reservoirs to store water, which forces people to migrate from one place to another. Since this technology requires flow velocity

in place of reservoirs to generate energy, it does not require people to be displaced.

6. **Downstream stretch of river/ canal:** Hydrokinetic technology neither diverts nor stores the water upstream, and thus the downstream stretch does not get dried out. Therefore, the downstream biodiversity is not affected with the operation of hydrokinetic turbine.
7. **Groundwater level:** Alteration of the groundwater level usually happens in dam-based schemes and run-of-river schemes. However, in projects using the hydrokinetic technology, the pathway of a river or an unlined channel is not altered/transformed for the operation of a hydrokinetic turbine, and thus the natural groundwater level is not altered.
8. **Greenhouse gases:** The contribution to greenhouse gas emission is nil.
9. **Noise pollution:** Unlike the conventional hydro turbines, hydrokinetic turbines work on fewer rotations per minute (rpm) and thus produce very less noise.
10. **Land submergence:** The submergence of land takes place whenever the water is either stored or the water way is obstructed by a barrage. Since this technology does not require such structures, no land is submerged in the operation of hydrokinetic technology.

Hydrokinetic Turbines

The functioning of a hydrokinetic turbine is in principle similar to that of a wind turbine, the only difference being the fluid utilized. Here, instead of air, water is used, and hence these turbines are called hydrokinetic turbines. The turbines do not require any hydraulic head and are therefore also termed as water current turbines, free stream turbines, or zero head turbines. These turbines are categorized into two types, namely, axial flow and cross-flow turbines (Figure 2). The turbines whose rotational axis is parallel or inclined to the direction of water flow are known as axial flow turbines, and those whose rotational axis is perpendicular to the direction of water flow are known as cross-flow turbines. These turbines may have two, three, or multiple blades on the rotor. Axial flow turbines are preferred in marine environment, whereas cross-flow turbines are more suitable for rivers and canals due to the following reasons:

- » The cylindrical-shaped rotor of cross-flow turbines allows them to utilize the space in a more efficient manner. The rotor has a larger diameter than depth, which makes it easy to be swept in smaller depth.
- » Cross-flow turbines are better suited to handle debris problems and do not get clogged.
- » They provides an option to place the generator on one side of the bank, and thus no sealing arrangement is required, which reduces the cost.

In Eq. (2), the term power coefficient is a measure of turbine efficiency, which depends on tip speed ratio (TSR). TSR is defined as the ratio of the tangential velocity of the rotor to the velocity of the flow, and it is denoted by λ.

$$\lambda = \frac{\omega R}{V} \quad (3)$$

Here, ω is the angular velocity (rad/s), R is the rotor radius (m), and V is the flow velocity (m/s).

$$\omega = \frac{2\pi N}{60} \quad (4)$$

Here, N represents the rotations per minute (rpm). The optimum rpm is the one for which the turbine attains its maximum efficiency. Lesser rpm will

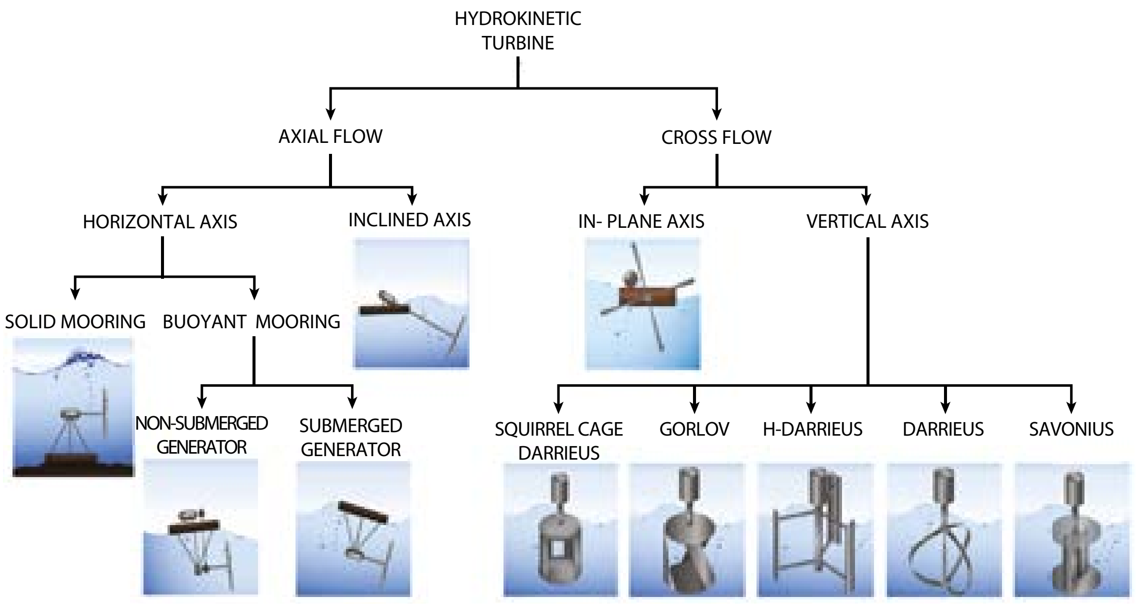


Figure 2 Types of axial flow and cross-flow turbines

Source *Sood and Singal (2019)*

result in slowing the rotational speed of the rotor, making it incapable of turning most of the water into energy, whereas higher rpm will generate higher rotational speed and cause turbulence. Thus, it is necessary to ensure time lapse between the movement of blades from similar locations. Since the power coefficient increases with increase in TSR and then starts decreasing due to development of turbulence because of high rotational speed, it is necessary to determine the optimum TSR value for which the power coefficient is maximum.

Potential of Hydrokinetic Energy in India

Theoretical, technical, and practical are the three classifications of hydrokinetic potential estimation. The total kinetic energy available in water is the theoretical hydrokinetic energy and the energy that can be extracted from the theoretical energy (due to device efficiency, site covered) is the technical energy. The sites that are not practicable for energy extraction due to social and environmental factors, such as fish habitats and navigation issues, must be avoided, and the remaining energy is known as the available practical hydrokinetic energy. Developing countries like India have many remote areas where water is available throughout the year. This available water can be utilized for energy generation and may help in changing the rural electrification scenario. The potential assessment of the hydrokinetic technology consists of the following five steps (Figure 3):

1. **Site characterization:** Each site has its own characteristics and its characterization pertains to the collection of its various properties, which include velocity distribution, bed surface profile, sediment properties, width, depth, temperature, and density. The measurement of site properties should be accurate, otherwise it will lead to significant error in the prediction of hydrokinetic energy.
2. **Device selection:** There are various cross-flow turbines suitable for rivers and man-made channels, but the selection of a particular turbine entirely depends on the properties of the site. A site with less flow velocity cannot be suitable to install a Darrieus turbine (see Figure 2) because of the self-starting problem. Likewise, Savonius turbines cannot be used in those sites that have higher flow velocity because their efficiency is low and if they are used, maximum flow velocity will go unutilized. It is, therefore, the site properties that govern the selection of a suitable hydrokinetic turbine.
3. **Impact on flow condition:** The hydrokinetic turbine during operation affects the flow condition upstream and downstream. This affected flow condition refers to the change in hydraulic behaviour of the channel/river. The change in hydraulic behaviour is due to reduced flow velocity and change in suspended sediment behaviour.

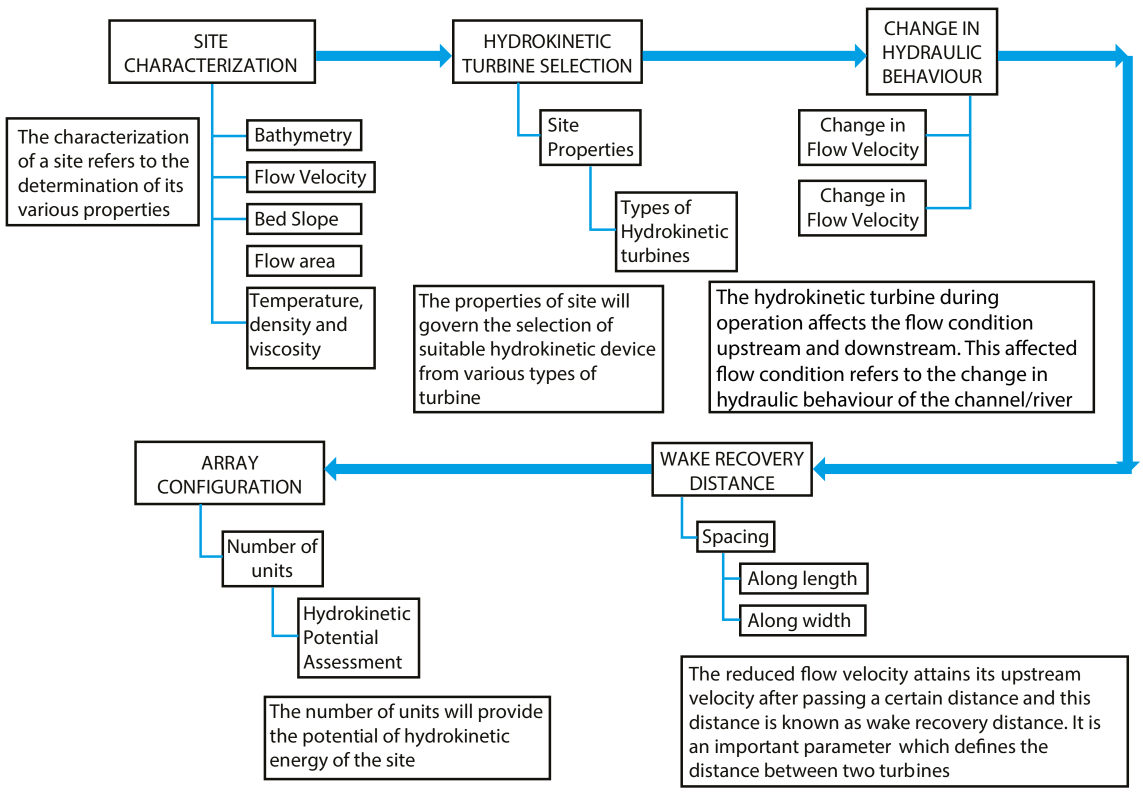


Figure 3 Steps for hydrokinetic potential assessment

This decreased flow velocity attains its upstream velocity after passing a certain distance and this distance is known as the wake recovery distance.

4. **Wake recovery distance:** Velocity deficit zone is the zone where velocity reduces to its lowest extent, and the zone in which the reduced velocity starts recovering is known as the far wake zone. The reduced flow velocity recovers due to surrounding flow mixing. It is an important parameter that defines the distance between two turbines.
5. **Array arrangement:** The determined wake recovery distance will decide the location of the second turbine and will be helpful in providing details regarding the number of units in a particular site. The number of units will state the potential of hydrokinetic energy for the site.

This technology can be used either as a stand-alone system or integrated to the power grid. Therefore, it will be a promising technology for remote areas. Large potential of hydrokinetic energy is available in Indian rivers and man-made channels. As far as the existing potential of hydrokinetic energy in India is concerned, no defined number is available till date.

Challenges in the Development of Hydrokinetic Technology

Hydrokinetic technology is under research and development phase and has to complete a long journey for its fruitful evolution. The technology is facing various challenges in its development (Table 2).

Conclusions

Hydropower must be handled in such a way that the extraction has a minimal detrimental impact on the environment and society. Kinetic energy of water is a promising source of renewable energy. The effective utilization of hydrokinetic technology will be not only useful for rural electrification of remote areas but also helpful in utilizing the irrigation canals for energy generation. Two types of data (i.e., temporal and spatial databases) are required for the accurate characterization of the flow. Site properties, suitable device selection, impact on flow condition due to device operation, wake recovery, and array arrangement are the interlinked steps required to assess the potential of hydrokinetic energy. Accurate resource assessment, device optimization, structural stability, reliability of technology, cost of energy, and lack of social awareness are the biggest hurdles in the development of the hydrokinetic technology. Optimal utilization of kinetic energy of water will be helpful in achieving the sustainable energy for the development of the nation. EF

Reference

Sood, M. and S. K. Singal. 2019. Development of hydrokinetic energy technology: a review. *International Journal of Energy Research* **43**(11).

Sunil Kumar Singal is Head, HRED, IIT Roorkee and Manoj Sood is Research Scholar, HRED, IIT Roorkee. They can be reached at sunilksingal@gmail.com and manojsood35@gmail.com

Table 2 Challenges in the development of hydrokinetic technology

Aspect	Challenges	Outlook
Resource assessment	Gauged stations are used for data collection in the hydrological method, which has the constraint to determine the flow velocity along the entire length of river reach. The database that may provide the details of flow characterization is not available	Two types of data (i.e., temporal and spatial database) are required for the accurate characterization of the flow
Turbine designing	Low starting torque, lower efficiency, and self-starting problem in cross-flow turbines	Hybrid turbines, that is, a combination of lift and drag based configuration, is under research for improving the torque fluctuations and removing self-starting problems
Structural stability, durability, and reliability of the technology	A complete unit of hydrokinetic system includes turbine, duct, mounting arrangement, mooring system, generator, and protection technique. Combination of the system requires structural stability in moving fluid at different flow velocities. The reliability of the hydrokinetic technology under normal and severe operating conditions is a big challenge in the development. The entire system is always in contact with water, air, and sunlight (in case of full or partial submergence)	Systematic arrangement for shutdown in a severe operating condition, proper coating, and maintenance and protection of the equipment is required
Cost of energy	Higher cost of energy will affect the growth of this upcoming technology and govern its success	Cost of energy can be controlled by increasing the number of units and simplifying the turbine design. The complex geometry increases the manufacturing cost and ultimately the cost of energy
Insufficient literature	Limited literature is available on hydrokinetic technology. Much of the literature is taken from the wind turbine technology	This technology requires social awareness for its rapid development

TRANSITION POTENTIAL TO NATURAL GAS IN THE MSME SECTOR IN INDIA'S NATIONAL CAPITAL REGION

The recognition of the importance of a road to a sustainable energy transition for India resonates in the policy priorities of the Government of India (GoI), which include India's Nationally Determined Contributions (INDCs) committed at the Conference of the Parties in Paris in 2015 (COP21) and the ambitious goals on renewable energy deployment and universal energy access. The GoI has also recognized the need to significantly expedite the consumption of natural gas (NG) so as to reduce air pollution across India, lower carbon intensity, and increase industrial growth.

In this context, TERI undertook a study to assess the potential and impact of a switch to NG from heavier polluting fuels in the MSME (Micro, Small and Medium Enterprises) sector of India's National Capital Region supported by the World Bank.[1] The project was initiated with an overall objective to assess the potential role of NG as a cleaner alternative for improving air quality in urban areas of India and inform policy for designing interventions to increase the uptake of gas.

The most significant process for usage of NG was found to be in burners and boilers, which require a substantial amount of heat for processing. However, it was observed that in some instances there was a lack of 'energy efficiency service providers' after the units have shifted to NG. Presence of energy efficient service providers enables the reduction of NG consumption through R&D measures undertaken during operations. For instance, in one of the steel industries in Badli Industrial Area, the NG consumption reduced by 30 SCM/ton from 120 SCM to 90 SCM/ton through R&D measures taken up by the industries. It was observed that polluting fuels are available in the market and some industries are still

[1] 'Study to assess potential and impact of switch to natural gas from heavier polluting fuels in India's National Capital Region MSMEs sector'

The industrial sector is a consumer of energy and a major contributor to greenhouse gas emissions and consequently the target of many government policies to transition to cleaner fuels. The micro, small and medium enterprises, however, are constrained by a number of unique challenges. In this article, **Jonathan D Syiemlieh** discusses the challenges and opportunities in transitioning these enterprises to natural gas.

using banned fuels. During field work, the TERI team learned that there was a switch from pet-coke to coal and fuel oil to low sulphur heavy stock (LSHS) in certain industries. The financial support provided by government agencies or financial institutions to industries for this transition towards cleaner fuels is also limited.

Moreover, it was also observed that a significant number of MSMEs were reluctant to make the switch from their existing fuel source to cleaner fuels. Unwillingness of MSMEs to move to NG may be attributed to high upfront costs, limited access of NG everywhere, and increased unit price of NG compared to other options (economic viability). A major proportion of MSMEs, specifically micro units, is located in non-conforming areas where NG penetration is a challenge. Among 'non-conforming' industrial areas are spaces of manufacturing activity that have emerged in and around residential areas, predominantly around urban and rural villages in response to a range of market demands. These areas are unplanned, unauthorized, and 'non-conforming' in the sense of being located in areas not zoned for industrial use. Many of these unplanned industrial areas could be said to have emerged on village lands earmarked for residential and agricultural use. NG supply utilities are averse to laying gas distribution network in such areas due to policy uncertainty surrounding investments in these areas. Furthermore, many units in non-conforming areas are not in favour of switching to alternative cleaner fuels as this would entail bringing them into the ambit of regulatory compliances.

At the same time, a large number of industrial units that fall in the ambit of 'conforming areas' have also not transitioned to NG in spite of the existence of city gas distribution (CGD) networks in these areas, which may be attributed to the weak marketing strategy of NG supply utilities. Nevertheless, in industrial units that have converted to NG, the role of NG in improving air quality, both indoor and outdoor, is quite evident.

From the perspective of CGDs in the Delhi NCR area, the key concerns in the adoption of NG include its price, lack of incentives, limited support from the government, and added switchover

costs. The delay in setting up the pipeline connectivity is attributed to the complexity in procedures, difficulty in getting right of way (RoW), and difficulties in obtaining permissions for laying pipelines.

A number of policy initiatives have been undertaken in favour of uptake and consumption of cleaner fuels by industries in the National Capital Region. The 'Cleaner Air Better Life Initiative' aimed at identifying key issues and possible solutions to polluting fuels and combustion sources of emissions was launched in November 2016 under the aegis of the Government of India. Some of the measures recommended to facilitate fuel switch in industrial units in NCR included ensuring liquefied petroleum gas (LPG) and piped NG (PNG) supply to all designated industrial areas in Delhi NCR on priority basis, formulation of better taxation strategies by the Ministry of Petroleum and Natural Gas (MoPNG) in coordination with the Ministry of Finance (MoF), notification of the list of approved fuels in the NCR by the respective state pollution control boards, and facilitation of CGD in all NCR towns wherever the supply of NG currently does not exist. With effect from November 1, 2017, the Supreme Court banned the use of petroleum coke (PC) and furnace oil (FO) for combustion in the states of Delhi, Haryana, Rajasthan, and Uttar Pradesh. The Delhi Pollution Control Committee (DPCC) notified a list of fuels permissible for the industrial use within the NCT of Delhi in June 2018. They include BS-VI petrol and diesel, CNG, LPG, aviation turbine fuel, biogas, and so on. This is an amendment of the original list of approved fuels notified by the Delhi Government on August 27, 1996.

A relevant example that highlights how policy initiatives can lead to mandatory switchover in a phased manner is the case of the Firozabad glass cluster in Uttar Pradesh. Industry associations have proposed the phased introduction of regulatory compliance in switching to clean fuels in categorized regions. The case study of the metal casting MSME unit in Faridabad, Haryana highlights that in addition to adopting NG as the fuel, MSME units need to follow the best operating practices in order to improve the energy efficiency of their operations. This requires understanding of technology best practices and their assimilation and adaptation to meet the needs of individual MSME units.

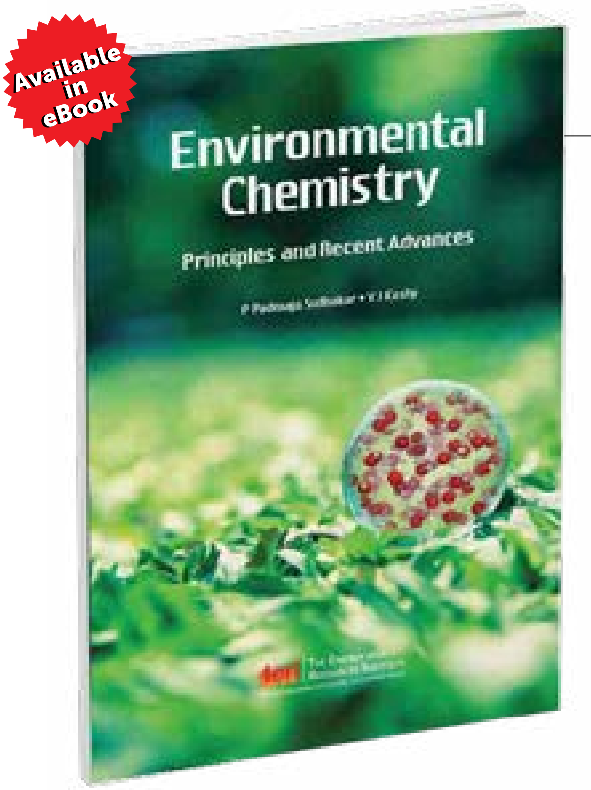
The cost competitiveness of clean fuels is a critical factor in clean energy transitions. At present, coal and pet-coke are highly competitive as compared to NG. Our study, however, found that energy efficiency improvements could potentially bring down the cost of NG to break-even. The competitiveness of liquid fuels such as light diesel oil (LDO), high speed diesel (HSD), furnace oil, and LSHS (on energy equivalent basis) is fluctuating because of factors such as the volatility of global crude oil and NG prices, government policies, and the cost of transportation. This provides an opportunity for NG penetration, provided the prices are rationalized, energy efficiency measures are put in place, and proper regulations are imposed to restrict the consumption of polluting fuels.

In order to spur increased use of NG, the study recommended adopting a cluster-based approach for the penetration of NG in the MSME units, recognizing well-defined potential users of NG, improving the availability of appropriate information related to NG use and contract-related arrangements, identifying technology and finance-related needs in monitoring and evaluation, and reducing transaction costs. The involvement of government agencies, CGD companies, legal and financial institutions, industry associations, and chambers of commerce is imperative to provide all-round support to MSME units, extended through cluster level stakeholder engagements. The regulations in the MSME sector have provisions for allowing the upgradation of technologies and the application of new clean technologies, and there is scope for capitalizing on this. The role of the government in the large-scale adoption of NG by the MSMEs by facilitating the creation of necessary infrastructure to ensure the reliable supply of NG at subsidized rates is also important. Various government departments have programmes and schemes related to enhancing clean energy measures but are working in silos. Therefore, an effective multi-level approach to governance encompassing vertical and horizontal dimensions through actor- and issue-based approaches can help in efficient coordination, leading to the convergence of actions. EF

Jonathan D Syiemlieh is Associate Fellow, Resource Efficiency & Governance Division, TERI, New Delhi.

teri

A STUDY OF THE CHEMICAL PHENOMENA IN THE ENVIRONMENT



Major topics covered

- Fundamentals of chemical thermodynamics
- Atmospheric chemistry
- Hydrospheric chemistry
- Soil and soil pollution
- Solid and hazardous waste management
- Environmental toxicology
- Radiation pollution
- Global environmental disasters

ISBN: 9788179935224 • Price: ₹650.00

Environmental Chemistry: principles and recent advances discusses the various pollutants present in the atmosphere, including persistent and bioaccumulative chemicals, pesticides, nanoparticles, and chiral pollutants. Advances in treatment techniques and analysis and monitoring of pollutants are the other topics covered in detail. A chapter has been dedicated for a comprehensive discussion on green chemistry. The book also talks about the Best Available Techniques (BAT) adapted by industries for Preventing and Controlling Pollution and also provides information on the application of analytical techniques, such as GC, LC, IR, and MS for analysing and measuring aqueous, solid and atmospheric samples and for monitoring environmental pollutants.

The Energy and Resources Institute
Attn: TERI Press
Darbari Seth Block
IHC Complex, Lodhi Road
New Delhi – 110 003/India

Tel. 2468 2100
Fax: 2468 2144
India +91 • Delhi (0)11
Email: teripress@teri.res.in
Web: http://bookstore.teri.res.in

To purchase the book, visit our online bookstore at http://bookstore.teri.res.in or send us your demand draft or cheque in favour of TERI, payable at New Delhi (outstation cheques are not accepted).

A Day-Ahead and Real-Time Dispatch Model for Scheduling of Round-the-Clock Renewable Power with Flexible Ramp Capacity

The infirm nature of renewable energy has traditionally been a challenge to its large-scale adoption as a source of power in the electricity grid. Considering the shortage of flexibility in the wind–photovoltaic–storage hybrid system with high penetration of renewable energy resources, **Radhey Shyam Meena**, **P V Tarun Saketh**, **Dilip Nigam**, **Sunil K Gupta**, **A S Parira**, **A K Tripathi**, **Rohit Bhakar**, **D K Palwalia**, **Neeraj Garg**, and **Shiv Lal** propose that emerging flexible resources including wind–photovoltaic, and energy storage can be used to provide flexible ramp capacity to improve flexibility. The authors discuss a two-stage stochastic dispatch model with 1 h day-ahead unit commitment and 15 min real-time economic dispatch to alleviate the shortage of operation flexibility.

In 2015, India submitted its Intended Nationally Determined Contributions (INDCs) on the sidelines of COP21 in Paris, highlighting its pathway to sustainable development. In its commitment, India has set an ambitious target of deploying 175 GW of renewable energy (RE) capacity by 2022. This target has now been raised to 227 GW, considering that the country is well on its way to exceeding the previously set target. However, in order to overcome the intermittency issues and to supply firm renewable power on round-the-clock (RTC) basis, the combination of renewable power projects and storage facility would be the only viable solution. Integrating renewable sources with various viable storage systems at the generation end has the potential to supply firm renewable power on RTC basis. Further, such techniques have the ability to extend supply hours of renewable energy generation to cover the peak load periods and also to supply on-demand firm renewable power on schedulable basis. Therefore, such projects would provide the flexibility to supply renewable power on demand as per the base load and peak load requirements of distribution companies (DISCOMs), thus matching their exact load demand pattern. With the increased uncertainty of net load induced from high penetration of renewable energy resources, more flexibility is needed in power systems to maintain power balance.

Considering the shortage of flexibility in the wind–photovoltaic–storage hybrid system with high penetration of renewable energy resources, this article proposes that emerging flexible resources including wind-photovoltaic, and energy storage provide flexible ramp capacity to improve flexibility. Considering the uncertainty of load-wind, and photovoltaic, the wind–photovoltaic–storage providing the flexible ramp capacity is integrated into a two-stage stochastic dispatch model, including 1 h day-ahead unit commitment and 15 min real-time economic dispatch. The efficiency of the proposed model is tested and simulations are carried out on a modified IEEE 118-bus with 54 thermal units, and the results indicate that wind–photovoltaic–storage providing flexible ramp capacity can effectively alleviate the shortage of operation flexibility and improve the overall economic benefit.

Background

To reduce the emission intensity of its GDP by 33–35 per cent by 2030 from the 2005 level and to achieve about 40 per cent cumulative electric power installed capacity from non-fossil fuel-based energy resources by 2030, India has set its renewable energy capacity addition target to 175 GW by 2022. However, the Government of India recently further raised the targets to