INDIA'S ENERGY FUTURE

DESIGNING AND IMPLEMENTING A SUSTAINABLE POWER MIX

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Designing and Implementing a Sustainable Power Mix

T.C.A. Avni, Astha Gupta, Michael Kugelman, Lydia Powell, and A.K. Saxena

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According to the International Energy Agency (IEA), electricity demand in India is expected to grow by 5% per year, nearly tripling overall power demand by 2040. Hence, India's future power mix will be the most important factor in achieving the country's goals for energy security and reducing carbon emissions. India seemed to be on a path to ramping up renewable energy to hit its target to install 175 gigawatts (GW) of renewable energy capacity by 2022. However, progress was slowed throughout 2021, due to the ongoing economic recovery from the Covid-19 pandemic. The result is elevated concerns over the country's ability to hit the 2022 target and the more ambitious 450 GW target by 2030. Other major questions remain about the enormous challenge of integrating intermittent renewable capacity into antiquated transmission grids and ensuring that grids have the flexibility to absorb that capacity expansion.

Despite positive momentum for renewables, India still has a long way to go in reducing its heavy dependence on coal. It is the second-largest consumer of coal globally, and approximately 70% of the country's electricity was generated by coal in 2020. Coal consumption rose by over 50% in just the past decade. The announcement during the 26th UN climate conference in Glasgow in November 2021 that India would become a carbon-neutral economy by 2070 was immediately met with questions about how emissions will be phased down, particularly given existing plans to increase domestic coal production.

Meanwhile, despite the government's stated goal to make India a cleaner, gas-based economy, the percentage of natural gas in the power mix remains low. Key challenges are price sensitivity to the relatively high-priced imported liquefied natural gas (LNG), the cost of building new infrastructure to receive and transport natural gas, and the issue of stranded assets with long-term strategies for renewables and net-zero transitions in mind. India's growing dependence on imported gas and the risks of supply disruptions are also key strategic concerns.

In addition to these domestic policy challenges, India faces an increasingly complex regional strategic context that affects the potential for regional energy cooperation. China's Belt and Road Initiative remains a key point of regional competition and alternative source of energy investment. Tense Sino-Indian relations are regularly exacerbated by India's partnership with other regional powers, including Japan, Australia, and the United States. As Michael Kugelman notes in his essay, the Quad presents an opportunity to address energy security concerns, but it is also a major sticking point in managing relations with China. Additional efforts, such as the U.S.-India Strategic Clean Energy Partnership and the Japan-India Energy Dialogue, offer avenues for increased collaboration on energy security and clean technology development. Yet how each country will prioritize these initiatives, especially the issue of funding, remains a question.

Given the important questions that remain about how India can continue to build on its past achievements to address the numerous barriers outlined above, the theme of the 2021 Energy Security Program is "India's Energy Future: Designing and Implementing a Sustainable Power Mix." For seventeen years this program has provided an assessment of major developments in Asian energy markets and geopolitics to assist policymakers in better understanding and addressing the implications for energy and environmental security in the region. The 2021 program focused on a range of critical issues, including both the fuels and policy constraints affecting how India shapes its power mix, the huge investment needed in grids to ensure reliable access to electricity, and how power and energy policies can be reconciled with broader plans for national and global climate action.

The National Bureau of Asian Research (NBR) commissioned essays by four scholars with expertise on these issues. The preliminary findings were discussed at a virtual workshop on September 22–23, 2021, which NBR was pleased to once again co-host with the Wilson Center. The authors have drawn on feedback they received at the workshop to strengthen their research and findings.

In the opening essay, Michael Kugelman from the Wilson Center considers the way India is developing its power sector within the broader context of its bilateral and regional partnerships and questions of geopolitical competition. He notes that much of India's electricity mix depends on imports, making the power sector vulnerable to supply chain disruptions and maritime chokepoints. At the same time, regional electricity and infrastructure integration remains low, limiting the ability to rely on transborder electricity amid surges in demand. Finally, Kugelman provides an assessment of two institutions that hold the most promise in mitigating impacts from geopolitical tensions and strengthening regional energy security. While neither will address the technical and policy barriers to ensuring a reliable power sector in India, they can provide important avenues to bolster trade and economic resiliency to source fuels or materials.

The second essay by A.K. Saxena of The Energy and Resources Institute (TERI) and T.C.A. Avni, an independent researcher, examines the outlook for India's electricity sector and the projected fuel mix in the coming decades. They note that although there has been an ambitious transition to scale up renewable energy from coal and other carbon-intensive fuels, the grid remains relatively inflexible, limiting the ability to integrate the increasing capacity of renewables across the country and to respond to rapid fluctuations in demand. Saxena and Avni emphasize that the solution to this inflexibility will be multifaceted and must consider policy, social, land-use, regulatory, and market barriers, among other factors.

In the third essay, Astha Gupta, a consultant to the IEA and a 2020 NBR Asia EDGE Fellow, explores questions of how electricity is transmitted, with a specific focus on the role of distributed energy resources (DERs). She notes that although India has achieved universal electrification, the supply of electricity remains unreliable and often unaffordable, particularly for those in more remote areas. DERs, such as rooftop solar and mini-grids, can sidestep some of the challenges of constructing and operating large-scale power plants, including faster repair and installation, which is particularly important during natural disasters. They can also lower environmental footprints (in terms of both land use and pollution). Gupta examines the steps policymakers could take to address financing, pricing, and demand management.

The final essay by Lydia Powell of the Observer Research Foundation identifies the factors that shaped India's nationally determined contributions (NDCs) and assesses the likelihood of these factors withstanding policy and economic challenges as India endeavors to decarbonize. Although increasing the share of low-carbon fuels is critical, she emphasizes the need to reduce emission intensity across sectors as part of larger efforts to achieve and strengthen India's NDCs. Powell also outlines considerations for policymakers seeking to secure investments, balance development strategies, and manage consumption trends and norms.

Collectively, these four essays provide much-needed context for how the power sector fits into the broader questions facing India's economic, energy, and environmental security. The analysis stresses that it is necessary to consider the electricity sector in parallel with overall energy demand growth, as the two are intertwined, with far-reaching implications for both domestic and foreign policy. When considering the ongoing developments taking place in energy markets and the global efforts to mitigate climate change, securing the necessary financing and investment to support transitions will remain a key priority to meet demand for reliable and affordable electricity.

The 2021 program would not have been possible without the tremendous support, guidance, and dedication of a number of organizations and individuals whose efforts are particularly worthy of recognition. First, we are grateful to Chevron and ConocoPhillips for their ongoing sponsorship of this initiative. Their contributions are indispensable for the program's activities and research agenda. Second, over the past ten months we have received comments from numerous U.S. and South Asian scholars, representatives at international organizations and development banks, and government officials on how the region is approaching power sector development amid low-carbon transitions. While there are too many people and groups to list individually, the workshop and this report would not have been possible without their contributions.

Behind the scenes, Audrey Mossberger, Tom Lutken, Micah Sindelar, Chihiro Aita, and Kylie del Rosario of NBR worked tirelessly to develop the program and refine the policy discussions, as did Michael Kugelman and his team at the Wilson Center in support of the workshop. This report is the product of their hard work, as well as the efforts of numerous others. We hope that you enjoy the report as much as we enjoyed working on it.

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The Geopolitics of India's Power Sector

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NOTE: The author is grateful to former Wilson Center intern Maha Hassan for her research assistance.

EXECUTIVE SUMMARY

This essay highlights the geopolitical factors that both hinder and help India's efforts to strengthen its electricity sector and discusses how India can leverage its bilateral and regional relationships to achieve its electricity needs.

MAIN ARGUMENT

Although its energy mix is heavily dependent on imported fuels, India has the capacity to export power. However, the country's regional energy diplomacy is hampered by a poorly integrated region, diplomatic tensions with some of its neighbors, a worsening rivalry with China, and a lack of access to Afghanistan and Central Asia. Fortunately, India can find workarounds for these challenges by capitalizing on its growing energy relationship with the U.S. and deepening its engagement with two key regional organizations—the Bay of Bengal Initiative for Multisectoral Technical and Economic Cooperation (BIMSTEC) and the Quad.

POLICY IMPLICATIONS

- India's capacity to achieve a more secure and diverse electricity mix will be enhanced by better relations with its neighbors and stronger regional institutions.
- Efforts pursued abroad to strengthen India's electricity sector can also help advance broader foreign policy objectives. These goals include strengthening multilateralism and pursuing strategic autonomy, a form of statecraft that emphasizes flexibility and freedom of action.
- Any geopolitical successes that help India's electricity sector can only be sustained if New Delhi addresses the complex challenges existing within the electricity sector itself.

For several decades, India's basic energy security reality has gone unchanged: Hydrocarbon supplies at home cannot keep up with demand, obliging India to increase imports and fostering its dependence on fuels sourced from volatile regions. Today, as in the past, New Delhi seeks to address this conundrum by pushing for the production of more renewables at home, diversifying its base of overseas suppliers, and using powerful state-owned energy companies to pursue upstream investments abroad. India also continues to oversee a naval modernization program, with the hope that stronger power projection at sea will enable it to better protect its maritime energy trade.

However, India also confronts new geopolitical challenges that further constrain its efforts to meet its energy needs. These issues include a worsening rivalry with China and the Taliban's takeover of Afghanistan. The silver lining is that with electricity production exceeding consumption, India has the option of exporting electricity to promote regional power trade. The growing U.S.-India energy relationship can also further strengthen India's electricity sector. Additional opportunities lie in deepening energy partnerships within two key multilateral groupings—the Bay of Bengal Initiative for Multisectoral Technical and Economic Cooperation (BIMSTEC) and the Quad.

This essay examines the various geopolitical challenges and opportunities shaping India's ability to achieve a secure and diverse electricity mix. It first provides a brief outline of India's current energy and electricity mix and identifies the fuels at the center of conversations on energy trade and diplomacy. It then highlights major geopolitical barriers to strengthening India's power sector, both within South Asia and in the larger Indo-Pacific. Finally, the essay examines two institutions with the most promise for improving India's domestic electricity mix and regional energy security and concludes with key considerations for stakeholders.

India's Power Sector: A Snapshot

Over the last twenty years, demographic and economic growth has caused electricity consumption to increase by nearly threefold.[1] This consumption is not clean. Coal still makes up most installed power capacity and accounts for over 70% of total power generation. Yet solar and wind have taken on an increasing share of the mix in recent years. This development reflects broader energy trends as the share of renewables in India's overall energy mix is projected to increase by up to nearly 40% by 2030. However, coal remains king. Because domestic coal production cannot keep up with demand, and indigenously produced coal often does not meet the quality standards of steel plants, India has begun to import coal in recent years. Indonesia, South Africa, and Australia are its top suppliers.

Oil—another major component of India's overall energy mix—is also heavily imported. Iraq is the country's top supplier, followed by the United States, Nigeria, Saudi Arabia, and the United Arab Emirates (UAE). Furthermore, as India seeks to make its economy more gas dependent, it has ramped up gas imports, with top suppliers including Qatar and Nigeria.

This strong dependence on volatile regions and chokepoints for oil and gas supplies—for example, 65% of Indian oil imports must transit the Strait of Hormuz—underscores India's vulnerability to supply disruptions and price volatility. To mitigate these risks, it not only is

[1] Energy statistics and other information in this section are drawn from International Energy Agency (IEA), "India Energy Outlook 2021," February 2021, https://iea.blob.core.windows.net/assets/1de6d91e-e23f-4e02-b1fb-51fdd6283b22/India_Energy_Outlook_2021.pdf.

searching for suppliers in closer and more stable areas but is working to ramp up domestic production. NTPC, India's largest state-owned power utility, has pledged not to seek new coal imports between April 2021 and March 2022.[2] New Delhi has also announced a goal to reduce oil imports by 10% by 2022 and hopes to increase supply within its strategic energy reserves.

India has several advantages as it considers how to use energy diplomacy to bring more stability and sustainability to its power sector. One is that because electricity production exceeds consumption, India has the capacity to export power, thereby positioning the country to play a key role in cross-border electricity-sharing arrangements. Additionally, while it is a heavy importer of raw fuels, India does export refined oil and petroleum products. This ability gives it leverage as it pursues energy partnerships abroad.

New Delhi, however, still faces immense geopolitical obstacles—starting in its own neighborhood.

Geopolitical Challenges for India's Power Sector: Enduring and Emerging

The needs of India's electricity sector, and its energy industry more broadly, are immense. In theory, more energy diplomacy with broader Asia—with an eye toward developing electricity-sharing and other trade initiatives—can bring some relief. But this strategy is much easier said than done, for old and new reasons.

An enduring challenge is the lack of regional integration. Thanks to its poor roads, insufficient electricity grids, and lack of intraregional trade, South Asia is often described as one of the world's least integrated regions.[3] These challenges are compounded by long-standing diplomatic tensions—mainly between Pakistan and India, but also between Pakistan and Afghanistan. South Asia's leading regional organization, the South Asian Association for Regional Cooperation (SAARC), is woefully inefficient, primarily because the India-Pakistan dispute has paralyzed an organization that operates on the principle of unanimity. Unsurprisingly, regional electricity trade totals less than 1% of South Asia's total estimated capacity. Only 2% of India's generated power is transmitted across its borders.[4]

Regional integration obstacles are not new, but they have been compounded in recent years by growing tensions between India and neighbors other than Pakistan. India has experienced tensions with Nepal over their shared border and with Bangladesh over a new citizenship law that affects Bangladeshi migrants in India. Another challenge is India's deepening rivalry with China. Beijing has long been New Delhi's chief strategic competitor, but bilateral relations plunged to their lowest level in years last summer after a deadly border clash in the Ladakh region. These tensions preclude potential cooperation with China's Belt and Road Initiative (BRI), which entails investment in infrastructure, including power projects. Beijing has used infrastructure investment as a vehicle for deepening its footprint across South Asia, including Bangladesh, Maldives, and Nepal, which previously had close partnerships with New Delhi.

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2 Saurabh Chaturvedi, "India's NTPC Plans No Coal Imports Again in 2021–22," Argus Media, June 21, 2021, https://www.argusmedia.com/en/news/2226683-indias-ntpc-plans-no-coal-imports-again-in-202122.

3 Riya Sinha and Niara Sareen, "India's Limited Trade Connectivity with South Asia," Brookings Institution, May 26, 2020, https://www.brookings.edu/research/indias-limited-trade-connectivity-with-south-asia.

4 Sanjeev Ahluwalia, "National Electricity Policy 2021: Making India's Power Sector Future-Ready," Observer Research Foundation, Special Report, no. 140, June 2021, https://www.orfonline.org/research/national-electricity-policy-2021-making-indias-power-sector-future-ready/#_edn8.

Admittedly, New Delhi rejected BRI back in 2017, before bilateral relations took a plunge, because its projects are envisioned to pass through Pakistan-administered Kashmir—territory that India claims as its own.[5] Nevertheless, deepening India-China tensions have deleteriously affected bilateral energy cooperation, which is modest but real. Just weeks before the Ladakh clash, Indian refineries were shipping diesel to China—a top importer of Indian petroleum products. After the clash, India imposed restrictions on energy trade with China as a part of its decision to curb commercial relations.[6] Other energy cooperation has included Indian investment in a China-Myanmar pipeline and an investment partnership with Beijing in oil stakes in the UAE. India also imports solar panels from China.

Newer geopolitical challenges emanate from Afghanistan and Central Asia. The Taliban takeover of Afghanistan delivered a major blow to India, which had enjoyed close ties with all non-Taliban governments since 2001. Only in June 2021, soon before the Taliban seized power, did India open up communication channels with the Taliban. Pakistan, India's bitter rival and the Taliban's main sponsor, is now poised to deepen its footprint in Afghanistan, as is Pakistan's ally China. Beijing has cultivated relations with the Taliban in recent years and has been praised by the new Taliban regime.

Adding a new dimension to Sino-Indian challenges, China hopes to bring infrastructure investment into Afghanistan, if the security environment is sufficiently stable, and Pakistan hopes that related projects can expand into gas-rich Central Asia. Indian infrastructure development in Afghanistan and energy investment in Central Asia will now be even taller orders than they already were. Pakistan, which borders Afghanistan to the east, has long denied transit trade rights to New Delhi. But now India risks being locked out of Afghanistan by the Taliban, by its rivals Pakistan and China, and by other countries, such as Russia and Turkey, that have grown closer to Pakistan and China and experienced setbacks in their relationships with India.

The silver lining for New Delhi is that one legacy project, the Turkmenistan-Afghanistan-Pakistan-India (TAPI) gas pipeline, has received a boost. With the conflict having ended in Afghanistan (at least for now), instability—one of the major obstacles to construction—should ease. Additionally, the Taliban has formally endorsed and vowed to "safeguard" the TAPI project, as well as any "national projects" that serve the interest of Afghans and contribute to development and prosperity. The Taliban has used this language consistently for nearly five years.[7] Still, financing and other challenges mean that the pipeline remains a long way from fruition. Furthermore, despite reassurances, the Taliban does not have a strong track record of protecting energy infrastructure. Over the years, it has attacked and destroyed electricity pylons in Afghanistan, causing many millions of dollars in damage. To be sure, however, now that the

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5 See "Official Spokesperson's Response to a Query on Participation of India in OBOR/BRI Forum," Ministry of External Affairs (India), May 13, 2017, https://mea.gov.in/media-briefings.htm?dtl/28463/Official+Spokespersons+response+to+a+query+on+participation+of+India+in+OBORBRI+Forum. The reasons for New Delhi's rejection of BRI were spelled out in more detail by India's external affairs minister in 2019. See "Question No. 849 One Belt One Road Initiative," Lok Sabha (India), June 26, 2019, https://mea.gov.in/lok-sabha.htm?dtl/31484/QUESTION+NO849+ONE+BELT+AND+ONE+ROAD+INITIATIVE.

6 Shine Jacob, "India Refiners Export Diesel to China as Beijing Recovers From COVID-19," *Business Standard*, April 23, 2020, https://www.business-standard.com/article/companies/indian-refiners-export-diesel-to-china-as-beijing-recovers-from-covid-19-120042201719_1.html; and Nidhi Verma, "Exclusive: Indian State Refiners Halt Oil Imports from Chinese Companies, Sources Say," Reuters, August 27, 2020, https://www.reuters.com/article/us-india-china-oil-exclusive/exclusive-indian-state-refiners-halt-oil-imports-from-chinese-cos-sources-say-idUSKBN25N1DQ.

7 Bruce Pannier and Abubakar Siddique, "What Happened When the Taliban Visited Turkmenistan," Radio Free Europe/Radio Liberty, February 11, 2021, https://www.rferl.org/a/taliban-turkmenistan/31098344.html. The Taliban first endorsed TAPI back in 2016. See Catherine Putz, "Taliban Pledge to Protect Infrastructure Projects," *Diplomat*, December 1, 2016, https://thediplomat.com/2016/12/taliban-pledge-to-protect-infrastructure-projects.

Taliban is running a government instead of waging an insurgency, it no longer has an interest in participating in such destructive acts.

Two Organizations, Two Opportunities to Strengthen Energy Security

Despite these obstacles, India can capitalize on two opportunities. One involves leveraging its membership in BIMSTEC, the "other" South Asia regional organization. BIMSTEC is more active and dynamic than SAARC in great part because Pakistan's absence from the group means that the India-Pakistan dispute does not act as a constraint. The other opportunity is pursuing energy cooperation within the Quad—a grouping comprising India as well as the United States, Australia, and Japan, all countries that can help New Delhi achieve its energy goals. Like BIMSTEC, the Quad is experiencing considerable momentum, largely because each member's relationship with Beijing has taken a major tumble.

The Benefits of BIMSTEC

India can point to few examples of regional energy cooperation, but much of what has taken place has involved the BIMSTEC states. Over the last few years, India has inked new accords that involve all other member countries: Bangladesh, Bhutan, Myanmar, Nepal, Sri Lanka, and Thailand. ONGC Videsh, the overseas arm of India's main state-owned oil and natural gas company, has investments in Bangladesh and Myanmar. The last few years have seen several BIMSTEC framework agreements on electricity cooperation, including memoranda of understanding that establish blueprints for interconnected grids.[8] India has done its part to translate this vision into reality. In 2018, New Delhi changed its policies on cross-border electricity trade by approving the use of its transmission lines by other countries. This has paved the way for electricity-sharing deals, including one signed by Bangladesh and Nepal in 2019.[9]

A heightened focus on BIMSTEC energy partnerships would be an easy lift for New Delhi, which has already demonstrated its preference for this regional grouping over SAARC. In 2019, Foreign Minister S. Jaishankar declared that BIMSTEC would be a priority over the next five years.[10] Notably, when Narendra Modi was re-elected prime minister that year, BIMSTEC leaders—not SAARC leaders—were invited to his swearing-in ceremony.

To be sure, BIMSTEC faces several challenges. One is financing. The organization is underfunded, which could constrain its ability to achieve its electricity-related goals. BIMSTEC will need more support from India and Bangladesh—the group's two largest economies—to become more financially robust. There may be scope for U.S. support, as well. The U.S. Agency for International Development (USAID) backs the South Asia Regional Initiative for Energy, an India-headed grouping that also includes fellow BIMSTEC members Bangladesh and Sri Lanka and supports the development of electricity transmission projects.

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8 "Memorandum of Understanding for Establishment of the BIMSTEC Grid Interconnection," Ministry of Power (India), August 31, 2018, https://powermin.gov.in/sites/default/files/uploads/BIMSTEC_MoU.pdf.

9 Prahlad Rijal, "Nepal, Bangladesh to Use Indian Grid for Power Trade," *Kathmandu Post*, June 23, 2019, https://kathmandupost.com/money/2019/06/23/nepal-bangladesh-to-use-indian-grid-for-power-trade.

10 "SAARC Has Issues, BIMSTEC Possibilities, Says Foreign Minister S Jaishankar," *Hindustan Times*, June 6, 2019, https://www.hindustantimes.com/india-news/saarc-has-issues-bimstec-possibilities-says-jaishankar/story-XVjyLBAwIfmbaL8dMJBUSP.html. For more context on the SAARC vs. BIMSTEC debate, see Joyeeta Bhattacharjee, "SAARC vs. BIMSTEC: The Search for the Ideal Platform for Regional Cooperation," Observer Research Foundation, ORF Issue Brief, no. 226, January 2018, https://www.orfonline.org/research/saarc-vs-bimstec-the-search-for-the-ideal-platform-for-regional-cooperation.

Another challenge for BIMSTEC is diplomatic. As noted earlier, India's tensions with its neighbors are not restricted to Pakistan. Relations with smaller states in South Asia have also been strained at times, due in great part to their unease about India being the region's most economically and militarily powerful player. New Delhi will need to work to reduce this mistrust harbored by its neighbors. One way to do so is to underscore the common interest it shares with its neighbors in partnering within BIMSTEC to strengthen domestic energy security. New Delhi is on the right track on this broader front of pursuing greater regional cooperation. It has a policy in place, known as "Neighborhood First," which aims to strengthen neighborhood ties, but so far the results have been mixed.[11] At the same time, deeper engagement with BIMSTEC itself can be a confidence-building measure if India and other South Asian BIMSTEC members can build trust by cooperating more extensively within the organization.

Additionally, political instability in Thailand and especially Myanmar poses a very real threat and could even present security risks to infrastructure development. The failure of attempts to ink a BIMSTEC free trade agreement is another setback that could constrain energy commerce. But for India the benefits of looking to BIMSTEC as an institutional anchor for energy cooperation are hard to overstate. Its member states are home to around a quarter of the world's population and have a combined GDP of nearly $3 trillion. New Delhi can further enhance energy diplomacy opportunities within BIMSTEC by pushing for expanded membership. Indonesia, which abuts the southeastern boundary of the Bay of Bengal, is India's top coal supplier and a logical candidate to join BIMSTEC.

The Merits of the Quad

The Quad has become one of the most dynamic multilateral groupings in the Indo-Pacific region. An important milestone occurred in November 2020 when the Quad navies held a major military exercise in the Indian Ocean. In 2021, the four members held a leaders-level meeting for the first time and announced a joint initiative to fight the Covid-19 pandemic. Later in 2021, the four leaders met in person at the White House. The Quad is a logical space for India to pursue energy diplomacy. It comprises three of New Delhi's closest partners, and each can help promote India's energy security—especially the United States. Furthermore, two of the Quad's formal working groups—those focusing on technology and climate change—could advance energy cooperation. Yet, while naval exercises have been a regular feature of the Quad, it is too early to tell whether maritime cooperation may eventually be leveraged to help secure supply routes for energy trade. Given the Quad's current emphasis on nonsecurity cooperation, maritime security initiatives beyond naval exercises are unlikely to be priorities, at least in the near term.

U.S.-India energy relations have made major strides over the last few years. A new strategic energy partnership accord was signed in 2018. U.S. crude oil exports to India skyrocketed from none in 2016 to over 90 million barrels in 2019. Indian energy companies, including the largest state-owned natural gas corporation, have invested at least $4 billion in U.S. shale gas assets. President Donald Trump's visit to India in February 2020 produced two energy agreements. One entails Exxon-Mobil helping India strengthen its natural gas distribution network. The other is a commitment from the U.S. International Development Finance Corporation (DFC) to

[11] See Constantino Xavier, "Modi's Neighborhood First Push Is Being Pulled Down by Decades of Policy Stagnation," *Print*, February 15, 2020, https://theprint.in/opinion/modis-neighbourhood-first-push-is-being-pulled-down-by-decades-of-policy-stagnation/365895.

establish a $600 million financing facility for renewable energy projects.[12] Nearly $300 million in DFC funds has already been invested in four different Indian solar power projects, and an additional $54 million in equity has been pledged for an infrastructure fund. In March 2021 the two governments pledged to revamp their strategic energy partnership so that it emphasizes clean energy cooperation.[13]

That same month, the Quad announced a Covid-19 vaccine agreement that entails India producing vaccines, the United States and Japan funding their production, and Australia distributing the vaccines across Southeast Asia. The four members can similarly leverage their respective advantages with energy. Washington can provide financing for clean fuels; Tokyo can supply technologies, especially those that can strengthen Indian capacities for battery storage in electric vehicles and more broadly enhance India's high-priority renewables sector; and Australia, a top overseas supplier of Indian energy, can provide subsidized gas and coal. In return, India can export refined petroleum (for which Australia is one of its top customers) and encourage its state-owned energy companies to invest in the other Quad countries' energy industries.

Conclusion

Deeper engagement with BIMSTEC and the Quad helps India advance not only its energy security goals but also its broader foreign policy objectives. New Delhi seeks to strengthen multilateralism and to practice a form of statecraft that ensures flexibility and freedom of action—a principle it refers to as strategic autonomy. This is a successor to the Cold War–era policy of nonalignment. For India, pursuing shared interests with its Asian neighbors and the United States within nonalliance groupings—in ways that do not tie it down—dovetails nicely with those goals.

Yet to continue to grow as a global power, India needs to ensure strong and sustained economic health—and that requires its energy needs to be met. India has a long way to go before becoming energy secure. While there are many geopolitical obstacles, the most complex challenges are arguably within the electricity sector itself. These range from distribution losses and other demand-side management problems to poorly coordinated grid systems and financial troubles. Although enhancing energy cooperation through BIMSTEC and the Quad would be helpful, these geopolitical successes can only be sustained if India gets its electricity sector in better working order.

12 Michael Kugelman, "Post-Trump's India Visit, the U.S.-India Partnership Is in a Good Place," *Asan Forum*, April 6, 2020, https://theasanforum.org/post-trumps-india-visit-the-us-india-partnership-is-in-a-good-place.

13 Kashish Parpiani, "Recommendations for India-U.S. Development Cooperation in the Indo Pacific," ORF, Issue Report, no. 476, July 2021, https://www.orfonline.org/research/recommendations-for-india-us-development-cooperation-in-the-indo-pacific.

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India's Electricity Outlook and the Challenges for Achieving a Sustainable Power Mix

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EXECUTIVE SUMMARY

This essay examines the near-term outlook for India's energy sector and considers the challenges facing the country's ambitious plans through 2030 for transitioning to renewable energy.

MAIN ARGUMENT

In recent decades, the electricity sector in India has seen a dramatic transition as the country achieves near-universal electrification, adequate generation reserves, and connectivity through a robust country-wide grid. The sector is also undergoing an ambitious transition toward higher shares of renewables on the back of increasingly competitive costs and commitments to address energy-related CO_2 emissions. In order to achieve the flexibility in grid operations required to accommodate the rising share of renewables, systematic changes will be necessary in almost all aspects of the power system—from passing new policies and regulations to building physical infrastructure and from managing demand response and optimal utilization of existing assets to introducing new technologies.

POLICY IMPLICATIONS

- Achieving India's stated policy goals will require making systematic changes in nearly all aspects of the power system, including supply and demand management, technology deployment, and infrastructure upgradation; resolving legacy challenges and distortions; addressing the social and political ramifications of the transition; increasing domestic manufacturing and supply chain reliability; and providing access to adequate and affordable financing mechanisms.
- Fulfilment of past commitments on climate finance and addressing concerns about developmental constraints and technology transfer will be critical to supporting India's transition.

India recognized the importance of sustainable fuel choices as early as the 1970s and promoted renewables, energy efficiency, and energy management practices even as it strove to meet its enormous developmental requirements. More recently, 2015 marked a seminal moment in the transition of India's power sector when the government committed to increasing non–fossil fuel power-generation capacity from 28% in 2015 to 40% in 2030 and installing 175 gigawatts (GW) of renewable capacity by 2022. The decision kick-started one of the world's largest programs to expand renewable capacity. Further increasing the scale of its ambition on climate action, India has recently committed to expanding installed renewable energy (RE) capacity to 450 GW by 2030.[1]

A modeling exercise by the Central Electricity Authority aimed to find the most cost-effective power mix for achieving optimal generation capacity in 2030 informed the share of RE to be of the order of 445 GW, or nearly 55% of total installed capacity.[2] The speed and scale of the changes required for this transition indicate India's sustained commitment and growing ambition, especially given the impacts of the Covid-19 pandemic.

This essay first examines the outlook for India's electricity sector as demand grows and the country continues to transition to cleaner fuels. The subsequent two sections then analyze the economics of its ambitious plans for RE and consider what must be done to turn these ambitions into realities, detailing how grid integration, energy storage, and other supply options can facilitate the energy transition. The final section expands the analysis beyond the electricity sector by looking at the impacts of social, political, and financial barriers to India's energy transition.

India's Electricity Outlook

Forecasting the extent of electricity demand growth in the coming decade is complex and fraught with uncertainty due to a number of factors. These include large-scale uncertainties in the rate and structure of economic growth, industrialization and urbanization, and lack of adequate data. The Energy and Resources Institute (TERI) projected in 2019 that Indian electricity demand (without losses, captive power, or behind-the-meter generation) would range from 2,040 to 2,857 terawatt-hours (TWh) in 2030. The wide spread between estimates stemmed from uncertainties in the assumptions about GDP growth rate, the macroeconomic levels of industrialization, and energy efficiency.[3] These projections are largely in line with other studies and the demand trajectory implied by the 19th Electric Power Survey of the Central Electricity Authority.[4]

The Covid-19 pandemic has been challenging in many ways. India's nationwide lockdown in 2020 to control the spread of the virus resulted in power demand falling by about 20%–30% compared to the corresponding period in 2019. While the historically unprecedented measures initially imposed in 2020 were slowly lifted, a resurgence of Covid-19 in 2021 led to regional economic disruptions. The effects of the pandemic on different sectors of the economy are still unfolding.

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1 "PM Modi Addresses Climate Action Summit," Press Information Bureau (India), Press Release, September 23, 2019, https://pib.gov.in/PressReleasePage.aspx?PRID=1585979.

2 Central Electricity Authority (CEA), "Report on Optimal Generation Capacity Mix for 2029–2030," January 2020, https://cea.nic.in/old/reports/others/planning/irp/Optimal_mix_report_2029-30_FINAL.pdf.

3 Thomas Spencer and Auyushi Awasthy, "Analysing and Projecting: Indian Electricity Demand to 2030," The Energy Resources Institute (TERI), February 2019.

4 Sahil Ali, "The Future of Indian Electricity Demand: How Much, By Whom, and Under What Conditions?" Brookings India, October 2018; and CEA, "19th Electric Power Survey," 2017.

A 2020 paper by TERI developed a framework to assess the potential impact of Covid-19.[5] In the scenarios considered, the GDP in 2025, though higher than the present level, remained lower than in the counterfactual pre-Covid-19 scenario. While assessments of impact on GDP growth are continually evolving, and estimates of GDP growth since publication of the paper have been revised upward, economic scarring and the difficulty of "catching up" indicate that economic growth in the near term would be lower than what would have been achieved in the absence of the pandemic. The extent of GDP contraction considered in the study ranged from 7% to 17%, with the projected impact on total electricity demand in 2025 ranging from 4% to 16% below the level implied by the pre-pandemic trend.

The Economics of Expanded Renewable Energy Commitments

The ambitious programs and initiatives for the deployment of clean energy technologies have benefited from falling global technology costs and seen recent wind and solar auctions deliver some of the lowest electricity prices in India. The expanded policy commitments for solar and wind capacity have charted the path for the decarbonization of the energy sector in India.

A recent study by TERI confirmed that shares of variable renewable energy (VRE) in total generation substantially above current levels would be cost-effective. The study analyzed scenarios with model assumptions on demand and technology costs that were consistent with the short-term evolution of the power system and that accounted for the sunk costs of existing assets (including coal, gas, and hydro) to co-optimize new capacity investment with low total system cost. It found that the VRE share in total electricity generation was economically attractive in the range of at least 35%–40% of total generation, with the solar and wind capacity share at 60% or more.[6] In a scenario family with varied assumptions, the share of wind and solar in total generation was found in the range of 38%–45% of total generation in all the scenarios except where additional VRE capacity was exogenously constrained. The substitution of fixed costs for variable costs as the share of renewables rises results in levelized system costs that change relatively little. In fact, total system costs initially fall marginally as the share of VRE increases because the high-marginal-cost coal and gas units are replaced with less expensive capacity.

A key insight from these scenarios is that the only cases where new coal is built are when the model is exogenously constrained to limit the addition of RE or investments in new gas are not allowed. This is because coal-based capacity is capital-intensive and needs to run at a higher utilization rate to be cost-effective. Consequently, given the costs at which renewables are now available, coal is no longer economically viable.

Integrating such a high share of renewables into electricity generation is technically challenging because the variability introduced is substantial. Taking the example of a simulated week in May 2030 with the level of VREs discussed above, the share of solar and wind in the total electricity generation varies from less than 15% in non-solar hours to more than 50% in solar hours. Increasing the penetration of VRE in grid operations will require significantly more power system flexibility to balance the variability in different timescales.

5 Thomas Spencer, "Bending the Curve: 2025 Forecasts for Electricity Demand by Sector and State in the Light of the Covid-19 Epidemic," TERI, July 2020.

6 Thomas Spencer et al., "A Model-Based Assessment of Variable Renewable Grid Integration Costs in India," TERI, February 2021.

Meeting daily, monthly, and seasonal balancing requirements, especially as current flexibility options are exceeded, will require a portfolio of cost-effective supply-side options to be developed from the dispatchable coal, gas, and hydro fleet; demand response and demand shifting; and the deployment of storage. These costs of adapting the power system to higher shares of VRE, referred to as grid integration costs, can be divided into the following categories: transmission, balancing, and profile costs. While grid integration costs are not unique to renewables, the spatial distribution of renewables, their lower-capacity utilization factors, and their short-term stochastic nature brings specific challenges. In addition, since VRE output is non-dispatchable and not perfectly correlated with load (even with perfect forecasts), other power system assets need to be available to supply load for hours when VRE is not available.[7]

What Needs to Be Done to Facilitate This Transition?

TERI's research indicates that the challenge of India's energy transition is not the cost of renewables but the speed and scale of transformation needed. Achieving India's stated policy goals requires systematic changes in almost all aspects of the power system, from policy and regulation to physical infrastructure and from management of demand response and optimal utilization of existing assets to the introduction of new technologies. This section considers several priorities for transitioning to a sustainable power mix.

Interstate Grids and Coordinated Scheduling and Dispatch

India's power system has the benefit of being one of the largest synchronous grids in the world. TERI's research shows that the most cost-effective way of increasing grid flexibility and utilizing existing generation assets will be through enhanced integration of the Indian power system, allowing complementarities between demand and supply across states and regions for seasonal balancing. For example, during the peak RE hours in a 2030 scenario, almost 40% of the demand is estimated to be met by the interstate transmission system because the amount of RE generated in RE-rich states is more than can be internally consumed. The situation would reverse in periods of high demand during non-solar hours when RE-rich states need to import power from coal- and hydro-rich states.[8]

The significance of interstate transmission is illustrated by the "high market purchase scenario" in the TERI study, where the optimal operation of interstate electricity markets allows large-scale, long-distance power flow.[9] As a result, the model does not find it necessary to build substantial pumped hydro or any new coal or gas capacity for seasonal balancing requirements in this scenario. Facilitating such a continuous transfer of electricity across long distances would require not only the extension of the physical transmission infrastructure but also the regulations and market development to provide the necessary price signals and enable coordinated scheduling and dispatch of supply resources at the regional and national levels.

India benefits from relatively strong central-level regulation of interstate transmission of electricity. The Central Electricity Regulatory Commission (CERC) has taken important steps

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7 Thomas Spencer et al., "Renewable Power Pathways: Modelling the Integration of Wind and Solar in India by 2030," TERI, July 2020.

8 Ibid.

9 Ibid.

toward promoting the economic dispatch of power, establishing a real-time electricity market, introducing security-constrained economic dispatch, and proposing to shift pan-India market-based economic dispatch.[10] The Ministry of Power has announced a phased approach for implementation of market-based economic dispatch, effective April 1, 2022.[11] The regulatory initiatives at the state level to enable greater penetration of renewables for energy security and the overall mitigation of climate change would go a long way in facilitating the energy transition in India.

Demand Side Management

As patterns of consumption change, so too does the traditional load profile. Indian load profiles are already becoming increasingly variable, with sharper morning and evening peaks. Increasing the share of variable renewables, especially solar, will further contribute due to their generation profile and intermittency. Managing consumer demand thus offers considerable potential for flexibility, with load shifting and peak shaving being some of the more cost-effective demand-side measures. These include programs for the promotion of energy conservation practices and efficient appliances for municipal and agricultural consumers (such as the National Street Lighting Program and promotion of energy efficient agricultural pump sets). Such initiatives assist in peak load management by improving energy efficiency and reducing overall demand.

The electricity distribution companies currently purchase most of their power through long-term power-purchase agreements with a largely fixed tariff. This system provides a limited signal for when additional generation is needed and little incentive for network or consumer efficiency.[12] More dynamic matching of supply and demand through the introduction of time-of-day pricing can incentivize consumers to adapt consumption patterns through appropriate price signals.[13] More complex agreements for voluntary demand reduction or curtailment, peak demand limiters, or automated control systems can further contribute to peak load management.[14]

Flexible Operation of Coal-Fired Fleet

In the short term, the existing generation capacity will play an important role in providing flexibility to the power system. In particular, India's substantial coal fleet is relatively young. Even though individual units may have limited flexibility in varying output during the course of a day, the fleet in aggregate can supply high amounts of flexibility if dispatch is coordinated, allowing it to supply daily and seasonal balancing to accommodate both wind and solar. However, the extent of the coal fleet's flexibility is constrained by the extent to which it can be backed down. While enhanced flexibility from the coal fleet can reduce the curtailment of wind and solar capacity, on days with maximum RE output some curtailment may still be necessary. This would be to the

10 Spencer et al., "Renewable Power Pathways."

11 "Framework for Implementation of Market Based Economic Despatch (MBED)—Phase1 for Lowering the Cost of Power Purchase to Consumers Released," Press Information Bureau (India), Press Release, October 8, 2021, https://pib.gov.in/PressReleasePage.aspx?PRID=1762042.

12 Rahul Tongia and Samantha Gross, "Working to Turn Ambition into Reality: The Politics and Economics of India's Turn to Renewable Power," Brookings Institution, September 2018.

13 Time-of-day pricing offers other advantages for greater RE integration by providing price signals to encourage the development of different types of electricity provision and services (e.g., for peaking power, fast-ramping power, storage, and ancillary services such as frequency support and ramping). For further discussion, see Tim Buckley et al., "Flexing India's Energy System: Making the Case for the Right Price Signals through Time-of-Day Pricing," Institute for Energy Economics and Financial Analysis (IEEFA), January 8, 2019.

14 Udetanshu et al., "Developing a Roadmap to a Flexible, Low-Carbon Indian Electricity System: Interim Findings," Climate Policy Initiative, February 13, 2019.

extent that coal plants cannot be ramped down further without switching them off, in which case insufficient capacity would be available to ramp up to meet the evening load.[15]

TERI's studies indicate that new coal capacity is unlikely to be economical when compared to renewables in the short term. Even with the addition of high RE capacity, the plant load factor of the coal fleet is likely to remain either at current levels or marginally higher.[16] An implication of this is that while coal capacity may not increase until 2030, absolute usage may increase given its role in providing supply flexibility to meet peak demand during off-solar hours.

The Role of Dispatchable Hydro

Across scenarios, dispatchable hydro (i.e., plants with reservoir, pondage, or pumped storage) also proves to be critical for providing additional supply-side flexibility. Hydropower provides peak support during the mornings and evenings, reducing output at times of higher availability of solar and wind power.

While hydropower projects have benefits beyond supplying flexibility to the power system and providing inertia,[17] building entirely new hydropower capacity faces a number of challenges, including in the acquisition of land, environmental and forest clearance, rehabilitation and resettlement of the project-affected communities, long gestation periods, and high investment costs. Moreover, a majority of India's hydropower potential is located in the Himalayas. The region is vulnerable to both seismic activity and extreme weather events, making construction more challenging. Build out of off-river pumped storage plants (PSPs) and solar-PSP hybrid projects merit due consideration. While solar-PSP hybrid projects offer the advantage of lower cost and lower construction-related risks, as well as shorter implementation time, the off-river PSPs provide good complementarity to meet the demand during periods of little or no VRE availability.

The Role of Battery Storage

Battery storage systems can absorb the excess solar output during midday and inject it back into the grid during the evening peak. In scenarios where substantial battery storage is considered, the curtailment of RE almost disappears, and the requirement for additional capacities to be online during the evening peak also decreases. This reduces the maximum coal capacities required as well as the need for aggressive cycling in the coal fleet.

Yet while battery energy storage systems have value in reducing the operational stress on the power system and supplementing its flexibility requirements, their current investment costs require high annual cycling to be cost-effective, limiting their role to daily balancing. As innovation continues and costs fall, battery energy storage will become increasingly cost-effective to meet balancing requirements.[18]

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15 Spencer et al., "Renewable Power Pathways."

16 Ibid.

17 Inertia in power systems refers to the energy stored in large rotating generators, which gives them the tendency to remain rotating. This stored energy can be particularly valuable when a large power plant fails, as it can temporarily make up for the power lost from the failed generator. This temporary response—which is typically available for a few seconds—allows the mechanical systems that control most power plants time to detect and respond to the failure.

18 Spencer et al., "A Model-Based Assessment of Variable Renewable Grid Integration Costs in India."

Other Supply Options

Gas. Gas is often discussed as a transition or bridge fuel, but natural gas plays a small role in India's power sector. This is likely to remain the case through 2030. Gas accounted for only 6.5% of total installed capacity in 2021, and a significant proportion of gas-based generation capacity in India is presently stranded due to lack of domestic supplies and the high cost of imports.[19] The dispatch of imported gas plants is low due to their high marginal cost.[20]

Nuclear power. While nuclear power offers a zero-carbon alternative to the supply mix, and the government has stated its commitment to developing India's nuclear energy capabilities, the growth of India's nuclear capacity has been modest. Nuclear capacity increased from 4.7 GW to 6.7 GW from 2012 to 2017, but it has plateaued at that level.[21] The long lead-times, capital intensity, history of time and cost overruns, and societal concerns about safety indicate that the role of nuclear power in India's power sector may remain modest through 2030.

Concentrating solar-thermal power (CSP). Because of its ability to store solar energy thermally and convert it back to power, CSP can deliver power on demand, making it a disruptive renewable technology.[22] CSP projects have, however, seen limited offtake worldwide, with global installations accounting for only 6.4 GW at the end of 2019.[23] CSP is expected to become more feasible in the near future as a result of several factors, including increased policy support, technological advances, the cost-effectiveness of thermal energy storage, and the development of economies of scale and manufacturing capability, among others.

Moreover, India has an immense solar power potential of over 2,700 GW through CSP.[24] Critical challenges for CSP are due to the lack of a reliable direct normal irradiance database, indigenous manufacturing capability, and competition from more cost-competitive photovoltaic (PV) technology. A case study on capital costs and the levelized cost of electricity for CSP indicated that even with indigenous manufacturing and economies of scale, the capital cost per megawatt (MW) of installed capacity would be higher than the CERC's benchmark costs.[25] Developing pilot projects at sites with the requisite solar insolation and bidding for solar thermal plants with storage would help discover the competitive costs associated with CSP technology in India.

Other Issues to Address in India's Electricity Transition

The Financial Health of Distribution Companies

The performance of state-owned distribution companies will be critical to the overall success of India's electricity transition. The financial health of these companies has steadily deteriorated, with total accumulated losses doubling between fiscal years 2013 and 2020, despite bailouts.[26]

[19] CEA, "Report on Optimal Generation Capacity Mix for 2029–30."

[20] Spencer et al., "Renewable Power Pathways."

[21] CEA, "Growth of Electricity Sector in India from 1947–2020," 2020.

[22] Susan Kraemer, "CSP Doesn't Compete with PV—It Competes with Gas," October 11, 2017.

[23] "Concentrated Solar Power Had a Global Total Installed Capacity of 6,451 MW in 2019," HeliosCSP, February 2, 2020, https://helioscsp.com/concentrated-solar-power-had-a-global-total-installed-capacity-of-6451-mw-in-2019.

[24] Ishan Purohit and Pallav Purohit, "Technical and Economic Potential of Concentrating Solar Power Generation in India," World Bank, 2021, https://openknowledge.worldbank.org/bitstream/handle/10986/29300/j.rser.2017.04.059.pdf?sequence=1&isAllowed=y.

[25] Suhas Bannur, "Concentrated Solar Power in India: Current Status, Challenges and Future Outlook," *Current Science* 115, no. 2 (2018).

[26] Power Finance Corporation, "Report on Performance of Power Utilities 2019–20," August 2021, https://www.pfcindia.com/DocumentRepository/ckfinder/files/Operations/Performance_Reports_of_State_Power_Utilities/Report_on_Performance_of_Power_Utilities_2019_20_29092021.pdf.

This has reduced their ability to invest in infrastructure, contract power supplies, provide quality service, and make timely payments to generators, which has follow-through effects on the entire power system.

There are a number of legacy challenges plaguing the sector as well, many of which have been exacerbated by the Covid-19 pandemic. At the heart of the issue is a mismatch between costs incurred in supplying power to consumers and revenue recovery—a gap that is not adequately met by subsidies from state governments. The distortions in price signals (with explicit rebates for residential and agricultural consumers subsidized by industrial and commercial users and by state governments) are compounded by a lack of regular tariff increases, poor billing and collection efficiencies, high technical and commercial losses, insufficient technical capacity, inadequate regulatory oversight, and delays or nonpayment of subsidies and dues by state governments.[27]

The distorted pricing mechanisms for retail supplies have follow-through effects as well. High electricity costs for manufacturing and industries reduce the competitiveness of these sectors and limit their ability to achieve scale and requisite growth, often forcing companies to reduce their reliance on grid electricity and invest in generation capacity for their own use ("captive" or self-generation). Simultaneously, the subsidized supply to agricultural and residential consumers encourages wasteful consumption, especially through excessive, inefficient groundwater withdrawal. The resulting uneven growth between consumer categories and the increasing shift toward captive generation lead to further losses for distribution companies, straining their capacity to make timely payments to generators or invest in requisite capacity and infrastructure to improve supply. Addressing the underlying issues in this vicious cycle affecting distribution companies will be a prerequisite for achieving many of the other reforms needed for India's energy transition.

Land Acquisition

Renewables are spatially dispersed and have a low power density, requiring larger areas than more power-dense technologies. Grid-connected wind and solar projects, for example, require land in excess of 2 hectares per MW.[28] India's push for utility-scale solar, while attempting to encourage use of wasteland, often faces constraints of land acquisition. Common challenges are the fragmented nature of land holding, poor records, disputed ownership, and additional restrictions on use. The result is a time-consuming and contentious acquisition process.

Reforms and initiatives are being undertaken to address these challenges, including the development of dedicated solar parks, the introduction of single-window clearances to expedite approvals, and the digitization and updating of land records. Support for land rentals, community projects (especially to develop barren land and encourage dual land use), and incentives for rooftop and floating solar can further help minimize total land-use requirements.

The Domestic Manufacture of Clean Energy Technologies

While India has made remarkable progress in the installation of RE-generation capacity, and most of its wind power equipment is sourced domestically, the country's solar capacity is still highly dependent on imports. In fact, more than 80% of the manufacturing value chain relies

[27] Ajay Shankar and T.C.A. Avni, "Resolving the Crisis in Power Distribution in India," TERI, Discussion Paper, August 2021.

[28] Sapan Thapar, Seema Sharma, and Ashu Elsevier, "Local Community as Shareholders in Clean Energy Projects: Innovation Strategy for Accelerating Renewable Energy Deployment in India," *Renewable Energy* 101 (2017): 873–85.

on imports, hindering India's ability to take advantage of rapid solar deployment. Concerns have been raised regarding the Indian solar PV projects that are showing degradation of panels at faster than expected rates, resulting in lower life expectancy and hidden costs.[29]

Moreover, past trends in globalization and manufacturing growth led to the manufacture of key intermediaries and entire production cycles becoming concentrated in specific regions. Disruptions in supply due to the Covid-19 pandemic exposed the dangers of monopolization and regional imbalance within supply chains. News reports of Chinese manufacturers reneging on contracts and raising prices for contracted equipment have increased international awareness and concern over supply chain and energy security.[30] Given the scale of India's ambition, ensuring domestic manufacturing capacity will be critical to mitigate these risks and provide further impetus to the clean energy transition. In this context, the government has been taking steps to enhance domestic manufacturing capabilities through incentives for investments in capital expenditure and production-linked incentives, as well as preferences for local suppliers, requirements for using domestic content, and the imposition of basic customs duties on solar PV-cell and module imports.[31]

Financing

India's energy transition, though economically viable in aggregate terms, is highly capital-intensive. Strong financial commitments and policy interventions by the central government and dynamic participation by the private sector have played a crucial role in accelerating the growth of renewables. While India's RE sector has received more than $42 billion in investment since 2014, achieving the stated policy goals by 2030 is estimated to require a further $500 billion.[32] Constraints on access to financing mechanisms—in terms of both adequacy and affordability—endanger the pace and efficiency of India's energy transition.

A study by the Climate Policy Initiative reported that the power-generation and transmission sector in India has been the primary recipient of green investments, with 85% of financing being raised from domestic sources.[33] Debt financing is the largest instrument to channel investments. However, the high cost of domestic capital, driven by the risks and uncertainties associated with investing in these projects for developing countries, creates challenges in raising funds. The involvement of international finance has been limited thus far. It is against this backdrop that it is important to note that even the commitments at the Conference of Parties in 2009 toward mobilizing $100 billion per year until 2020 for climate action (which have been criticized as being insufficient for meeting climate finance requirements of developing countries) have not been met.[34] Climate finance figures have been criticized for inconsistencies and methodological loopholes, ambiguity over definitions that creates false equivalences between loans and grants, and lack of agency by developing countries on the direction of fund flows.[35]

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29 "Policy Paper on Solar PV Manufacturing in India: Silicon Ingot & Wafer–PV Cell–PV Module," TERI, August 2019.

30 Utpal Bhaskar, "Hike in Solar Panel Prices by Chinese Cos to Hit Projects," *LiveMint*, April 1, 2021, https://www.livemint.com/news/india/hike-in-solar-panel-prices-by-chinese-cos-to-hit-projects-11617213860784.html.

31 "Manufacturing of Solar Modules," Ministry of New and Renewable Energy (India), August 5, 2021, http://164.100.24.220/loksabhaquestions/annex/176/AU2944.pdf.

32 Tim Buckley and Saurabh Trivedi, "Capital Flows Underpinning India's Energy Transformation: Global Capital Is Primed and Ready," IEEFA, February 2021.

33 Mahua Acharya et al., "Landscape of Green Finance in India," Climate Policy Initiative, September 11, 2020,

34 Ministry of Finance (India), *Economic Survey: 2020–21*, vol. 2 (New Delhi, 2021).

35 J. Timmons Roberts et al., "Rebooting a Failed Promise of Climate Finance," *Nature Climate Change* 11 (2021): 180–82.

Given the consumer constraints on access and affordability, India's energy transition is highly price-sensitive. Greater access to affordable financial solutions will be critical for realizing the country's clean energy ambitions and achieving national and global climate objectives. This will require transformative investment increases, enhanced financial resources, and both the fulfilment and scaling-up of commitments during climate negotiations to support equitable and just transitions.

Implications for Social Equity and Distributional Impacts

Coal is a major source of revenue in several Indian states and forms the backbone for local economies through the creation of jobs and development of infrastructure. Globally, the transition toward a cleaner electricity grid has been shown to have implications for the communities dependent on coal. A World Bank study in Eastern Europe, for example, found that mine closures led to a reduction in the number and quality of jobs five years afterward. In addition to these job losses, lower government revenue led to reduced budgets for municipal services and declining living standards, demonstrating the fragility of many mining communities.[36]

A TERI study mapped the impact of coal mines and their closures, discussing the social, political, and economic linkages in towns and communities dependent on coal. The study detailed the extent of coal's embeddedness in the local economy and the implications of mine closures for employment, per capita income, socioeconomic disparities, and the secondary and tertiary sectors.[37] In the absence of a roadmap for the region, closures had brought about a complex situation, with de-population, higher reported crime, increasing stress, and the formation of local political movements demanding the opening of new mines. In the absence of definite strategies to transition the workforce currently dependent on the coal sector, the transition to clean energy could erode the social and developmental gains already made, disproportionately affecting the poor and marginal.

Climate Vulnerability

Rising global temperatures have already caused changes in weather patterns and increased the intensity of extreme weather events. Climate change affects power system operation in a variety of ways, from planning and generation to utilization of electricity through transmission and distribution. Ensuring the reliability of supply in the face of adverse eventualities requires building redundancy in capacities and making capital-intensive investments. The costs of these mitigations are likely to rise with the increased frequency and intensity of high-impact events.

The rising share of VRE-based generation will bring its own challenges due to the intermittent nature of wind and solar generation and dependence of their output on external factors such as solar insolation levels and wind speeds.[38] As the impact of the sudden slowdown in wind-driven electricity generation on electricity markets in Europe and the United Kingdom recently showed, the increasing reliance on such intermittent generation sources, when coupled with greater unpredictability of climate and weather patterns, will require a re-evaluation of generation reserves.

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36 Michael Haney and Maria Shkaratan, "Mine Closure and its Impact on the Community: Five Years after Mine Closure in Romania, Russia and Ukraine," World Bank, 2003.

37 Ruchi Gupta, "Mapping the Impact of Coal Mines and Their Closure: A Case of Betul," TERI, March 2021.

38 S.R. Narasimhan, "Mitigating the Impacts of Disaster Events," *Energy Future*, October 2020.

Conclusion

India's energy future shows promising potential. Progressive policies and consistent commitments have allowed the country to maximize its latecomer advantage by adopting and investing in cleaner and more efficient technologies across the supply and demand value chain in the power sector. India's focus on actions that address developmental deficits, while synergizing economic growth with measures to mitigate climate change, has been vital to increasing its commitments to reducing emissions and promoting environmental sustainability.

However, the evolving costs of renewables and storage technologies, the rate and structure of India's economic and demand growth, and the ability to adapt the Indian power system at the speed and scale required to accommodate an increasing share of renewables will be key factors in India's electricity transition in the coming years. Important steps include creating public awareness of the cost of inaction, coordinating with stakeholders to address the concerns of vulnerable communities, and mobilizing adequate levels of financing. Moreover, these will require a supportive global environment in which India's international partners match and support its ambitious goals and deliver on their commitments for financing and technology transfer.

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The Potential of Distributed Energy Resources for India's Energy Security

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EXECUTIVE SUMMARY

This essay examines the role that distributed energy resources can play to ensure that India's transition to a cleaner energy mix is sustainable and affordable and considers policy options to achieve this goal.

MAIN ARGUMENT

Clean energy transitions are underway in India to meet international climate commitments and improve overall energy security in the country. This progress has come through massive deployment of renewable energy technologies and solutions mostly at the grid level. Distributed energy resources (DERs) hold great potential to address the challenges of India's energy security and make this transition more reliable, affordable, and sustainable. In addition to improved access, these distributed systems can bring the benefits of reliability to key sectors such as healthcare and agriculture. This untapped potential will require investment and administrative reforms, alongside existing government support. Such reforms could take full advantage of disruptive distributed technologies to ensure reliability and affordability for both consumers and utilities.

POLICY IMPLICATIONS

- Besides reducing emissions, DERs could provide socioeconomic and environmental benefits over large-scale, grid-level sources, including increased employment opportunities and reliability during storms or the ongoing pandemic.
- The Indian government must continue to expand existing efforts in support of private-sector initiatives to ramp up DERs by improving access to financing and removing regulatory hurdles.
- Coupling DERs to key sectors, such as health and agriculture, and modernizing the electricity distribution system could allow India to take full advantage of these disruptive technologies.

Historically, distributed energy resources (DERs) or decentralized renewable energy (RE) systems such as solar lanterns, solar home systems, and renewables-based micro or mini-grids were promoted in India to provide energy access in remote locations where grid extension was not considered feasible. While some of these systems are still able to supply reliable electricity to the remotest communities, the achievement of universal electricity access through more traditional, large-scale means has stalled their growth. Beyond universal electrification, India still lacks a secure, reliable, and affordable supply of electricity.

India is ambitiously driving an agenda of clean energy transitions. It achieved 100 gigawatts (GW) of RE capacity in August 2021 and is now ranked fourth globally in terms of RE capacity. The country further plans to reach 175 GW of RE by 2022 and 500 GW of non–fossil fuel capacity by 2030. The last decade witnessed accelerated deployment of utility-scale renewables, and this trend remained resilient during the Covid-19 pandemic. Utility-scale RE power plants have been largely supported by the government through conducive policies such as easing procedures for land acquisition, evacuation infrastructure, must-run status, purchase obligations, and competitive bidding.[1] At the same time, the deployment of DERs has not scaled up, despite the huge untapped potential.

India, like many countries in South Asia, faces limited land availability, high transmission and distribution (T&D) losses, and financially stressed distribution companies, among other constraints. During energy transitions, DERs offer opportunities to utilize limited land, bring generation closer to consumption, reduce electricity prices (especially for industrial and commercial consumers), and produce socioeconomic benefits. At several instances during the pandemic and extreme weather events, DERs have proved to be reliable and resilient.

DERs cover a wide range of systems. This essay will focus largely on the potential, reliability, and benefits of rooftop solar systems, solar photovoltaic (PV) water pumps, and mini-grids, which are more relevant to the market of India. The country continues research and demonstration of other DERs such as RE-based cold storage systems, solar dryers, and coolers for several decentralized applications. The essay first illustrates how DERs have demonstrated resilient and reliable electricity for communities in India and produced socioeconomic benefits. The essay then discusses the policy framework in India for encouraging distributed systems and compares Indian policies with those of other countries in South Asia. Finally, the essay considers options for scaling up DERs to enhance access to clean and reliable energy supply and meet growing demand in a secure and sustainable way that supports India's energy transition goals.

The Role of Distributed Energy Resources

Resilience and Reliability

DERs have shown resilience in supply of reliable electricity in India during both extreme weather events and the Covid-19 pandemic. Examples from Indian states vulnerable to extreme weather include a cyclone that hit the eastern coast in 2020. The cyclone was the strongest in the region this century, leaving many people displaced and without electricity supply for days due to damage to the grid distribution lines. A cluster of solar micro-grids that was set up in the

[1] Must-run status is given to those power plants that are not subject to curtailment or regulation of power on account of merit order dispatch or any other commercial consideration but only for reasons of the security of electricity grid.

Sundarbans islands prevented blackouts amid the devastation.[2] These micro-grids were repaired by the local technicians in a matter of hours and supplied electricity to the community.

Another example from India illustrates the reliability of distributed solar PV systems during the ongoing pandemic. Indian populations residing in villages have inadequate rural healthcare infrastructure, and reliable electricity access is the lifeline for any healthcare center operating to provide critical care. Therefore, taking proactive steps in this direction is vital and could help build resilience. A well-functioning distributed solar PV system installed in the healthcare center in a village of the state of Jharkhand, an area that is highly vulnerable to power outages from damage to the electrical grid, improved the critical care at the hospital immensely, providing the center with uninterrupted services. The reliable power from the solar PV system enhanced the community's self-reliance and increased resilience during the pandemic.

Potential Socioeconomic and Environmental Benefits

DERs are easy to install, repair, and operate compared to the utility-scale plant, and these systems could provide much-needed flexibility to the grid. At the same time, they have a great potential to generate local jobs (across the entire value chain, from installation to operation) and could reduce electricity bills for commercial and industrial consumers by offering lower prices than grid electricity. Further, deployment of DERs can reduce the consumption of fossil fuels such as diesel, thereby reducing carbon emissions.

Jobs and employment. Estimates show that distributed RE technologies such as rooftop solar, biomass, and small hydro can create more jobs for every megawatt (MW) of installed capacity than fossil fuel–based power generation. Among all the distributed energy technologies, rooftop solar can create the maximum employment of around 25 persons for every MW of installed capacity.[3] Further, rooftop solar tends to be more labor-intensive than utility RE projects; smaller project size in the case of rooftop solar requires more people for installation than utility projects. Rooftop solar jobs are distributed and localized, and large pipelines of projects at the subnational level create long-term employment opportunities. In India, 38,640 workers were employed for just 3.8 GW of cumulative rooftop solar capacity in fiscal year 2019.[4] By contrast, for the higher cumulative capacities of utility-scale solar (26.2 GW) and wind (35.6 GW), only 37,910 and 23,340 workers were employed, respectively. It is estimated that the 40 GW of rooftop solar planned by 2022 could create around 800,000 jobs in India.[5]

Benefits to business and industry. Across countries in South Asia, the uptake of grid electricity has increased considerably; however, ensuring reliable access is still a challenge, particularly from a business and industrial standpoint. In India, for example, while the uptake of grid electricity for households has increased over the years, around 40% of rural enterprises still rely on non-grid

2 Lou del Bello, "Plunged Towns into Darkness, One Community Kept the Lights On," Huffington Post, June 26, 2020, https://www.huffpost.com/entry/cyclone-amphan-electricity-microgrids-solar_n_5ef2fa8dc5b6aa825ac903f9.

3 COBENEFITS, "Future Skills and Job Creation with Renewable Energy in India Assessing the Co-benefits of Decarbonising the Power Sector," October 2019, https://www.ceew.in/sites/default/files/CEEW-%20COBENEFITS-Study-India-Employment%2031Jan20.pdf.

4 Neeraj Kuldeep et al., "Powering Jobs Growth with Green Energy," Council on Energy, Environment and Water (CEEW), Natural Resources Defense Council (NRDC), and Skill Council for Green Jobs, July 2019, https://www.ceew.in/sites/default/files/CEEW-Jobs-Issue-Brief-2019-2-web-24Jul19.pdf.

5 Arunabha Ghosh et al., "Filling the Skill Gap in India's Clean Energy Market Solar Energy Focus," CEEW and NDRC, February 2016, https://www.ceew.in/publications/filling-skill-gap-india%E2%80%99s-clean-energy-market.

sources such as solar home systems and mini-grids. The benefits of high-quality, reliable, and customized electricity services outpace the affordability challenges.[6]

An impact assessment study evaluated the solar irrigation program in India and found that on average 45% of farmers showed an increase of 50% or more in annual income over rainfed irrigation.[7] For comparison, the early results from a solar-powered irrigation system currently implemented by Gham Power in Nepal indicate a 30%–100% increase in net income for farmers, in addition to ensuring affordable and reliable irrigation.[8]

Industries and commercial consumers find rooftop systems financially more attractive. Such systems could bring savings on their electricity bills because the utilities in South Asia often charge high electricity prices to these consumers (often cross-subsidizing the residential consumers). It is estimated that the roughly 50 government buildings in India having a total solar potential of 5.9 GW could deliver annual savings of approximately $100 million.[9]

Environmental benefits. Full implementation of the Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan (PM-KUSUM) scheme in India could help abate around 32 million tonnes of CO2 emissions annually through replacing 8 million diesel irrigation pumps with solar-powered pumps.[10] Likewise, Bangladesh could reduce emissions by around 53,600 tonnes of CO_2 annually by installing two hundred solar mini-grids by 2025.[11] This is considering that a typical solar mini-grid, meeting annual demand of 400 MW per hour, emits approximately 90% less CO_2 than grid-connected power and diesel mini-grid alternatives.

Government Policies for Promoting Distributed Energy Systems

Government Policies

South Asian countries have made strides in expanding their electrification programs, but issues of reliable supply persist, particularly in remote areas. It is helpful to consider some of the similarities across the region. Quality of supply is a common problem, particularly for industrial and commercial consumers, suggesting opportunities for large companies, as well as small and medium-sized enterprises, to opt for distributed energy systems such as solar rooftop systems and mini-grids. While regional governments have started shifting policies and regulations to improve the reliability of the main grid, there is an increasing focus on the deployment of distributed solutions as alternatives to complement grid electricity and enhance access to electricity for all.

India has introduced various schemes for promoting distributed electricity in recent years, with specific targets for rooftop solar PV systems and solar PV water pumps. The government has announced an ambitious target of achieving 40 GW of rooftop solar PV by 2022, with net

6 Smart Power India, "Rural Electrification In India," 2021, https://smartpowerindia.org/media/1230/report_rural-electrification-in-india_customer-behaviour-and-demand.pdf.

7 Shikha Suman, "Evaluation and Impact Assessment of the Solar Irrigation Pumps Program in Andhra Pradesh and Chhattisgarh," Sampling Research, January 2018, https://www.ssael.co.in/images/Library/files/Solar-Pumps-Impact--SSAEL-Report.pdf.

8 Bishwaraj Bhattarai, "Gham Power: Lessons Learned from the Rural Electrification Micro-Grid Project in Nepal," June 5, 2020, GSMA, https://www.gsma.com/mobilefordevelopment/blog/gham-power-lessons-learned-from-the-rural-electrification-micro-grid-project-in-nepal.

9 Prashant Bhanware et al., "Renewable Energy Onsite Generation and Use in Buildings," Prayas (Energy Group), June 2017, https://www.prayaspune.org/peg/publications/item/348.html.

10 "PM KUSUM: Pradhan Mantri Kisan Urja Suraksha Evam Utthaan Mahabhiyan," Ministry of Information and Broadcasting (India), https://mnre.gov.in/img/documents/uploads/file_f-1632204688401.pdf.

11 "Solar Mini-Grids: Investment Case—Bangladesh," Vivid Economics, February 2019, https://cdkn.org/wp-content/uploads/2019/09/Investment-case-solar-mini-grids.pdf.

metering guidelines being issued by several states. The PM-KUSUM scheme promotes distributed energy generation through three key components. The first is encouraging farmer groups and cooperatives to set up RE power plants (with a capacity ranging from 500 kilowatts to 2 MW) on barren land. These power-generating plants will feed into the distribution substations, thereby reducing the T&D losses. The second component is a pilot program to solarize around one million electric irrigation pumps. The final component is to encourage farmers to set up around 1.75 million stand-alone solar irrigation pumps that can supply surplus power to the grid.

With this PM-KUSUM scheme, the Indian government plans to add 25 GW of solar and RE capacity by 2022.[12] Similar efforts to promote distributed RE technologies have been undertaken by other countries in South Asia. Bangladesh and Sri Lanka provide two examples:

- The government of Bangladesh enacted net-metering guidelines in August 2018 to encourage the use of vacant spaces and rooftops in solar power generation. Infrastructure Development Company Limited is leading efforts to deploy off-grid RE on a large scale in Bangladesh, with plans to install 50,000 solar irrigation pumps by 2025.
- The government of Sri Lanka introduced a net-metering scheme in 2010 and continued development of rooftop solar under the Soorya Bala Sangramaya (Battle for Solar Energy) program (introduced in 2016). It envisions the deployment of 1 GW of rooftop solar capacity by 2025.[13] This vision is supported by two additional schemes introduced under the Soorya Bala Sangramaya program—the net-accounting and net-plus schemes, which are aimed at encouraging industrial and small residential consumers to set up rooftop solar systems.

India still leads in the installation of solar irrigation pumps and rooftop solar PV systems, but other South Asian countries are following suit. Across the region these efforts have been the result of government initiatives and financing assistance. However, private-sector investment has also been a factor in many South Asian countries, particularly in the installation of mini-grids. The World Bank allocated $5.6 million for development of mini-grids in Nepal.[14] Likewise in India, the Rockefeller Foundation and Tata Power have joined forces to install 10,000 mini-grids by 2026.

India's Energy Transitions

With an increased focus on energy transitions, electricity from cleaner sources will penetrate more deeply into the demand sectors such as agriculture, buildings, and transportation, and it is expected that these consumers will take center stage in electricity production and consumption. The Indian government has come up with the "Electricity (Right to Consumers) Rules 2020," which develop guidelines that ensure minimum standards of electricity supply.[15] The rules give rights to general consumers as "prosumers," encouraging electricity generation through distributed resources. Amendments under consideration for these rules include encouraging consumers using diesel generators to move to RE with battery storage in the next five years. Further, the draft national electricity policy for 2021 explicitly asks distribution companies in areas prone to natural

12 Ministry of New and Renewable Energy (India), "Solar Schemes," https://mnre.gov.in/solar/schemes.

13 Arjun Dutt, "Accelerating Renewable Energy: Investments in Sri Lanka: Drivers, Risks, and Opportunities," CEEW, July 2020, https://cef.ceew.in/solutions-factory/publications/accelerating-investments-in-renewable-energy-in-sri-lanka-drivers-risks-and-opportunities.pdf.

14 REN21, *Renewables 2020 Global Status Report* (Paris: REN21 Secretariat, 2020), https://www.ren21.net/wp-content/uploads/2019/05/gsr_2020_full_report_en.pdf.

15 The rules are available from the Ministry of Power (India) at https://powermin.gov.in/sites/default/files/uploads/Consumers_Rules_2020.pdf.

disasters to explore the possibility of automatic islanding of distribution systems into multiple micro-grids with distribution generation.

During energy transitions, DERs can support India's dynamic power system by bringing more flexibility to the grid. Concerning demand response, agricultural users are already participating in energy supply/demand balancing through involuntary irrigation load shifting (passive consumption), and analysis by the International Energy Agency (IEA) foresees more active participation of agriculture, industry, and the building (including cooling) sector by 2030.[16] India would need to redesign regulatory frameworks to provide price signals (through the introduction of time-of-day and time-of-use tariffs) for demand response, as new technologies for clean energy generation get closer to the demand side. Demand response will be further enabled by advanced digital and smart metering and automation, which India is already building as part of its modernization strategy for electricity utilities.

Recommendations to Scale Up Distributed Energy Resources

This section provides a set of recommendations for India to accelerate the deployment of DERs, making the access through these systems more reliable, secure, and sustainable. The renewed interest in DERs in India goes beyond providing energy access to include decarbonizing demand sectors, overcoming the unreliability of electricity, and improving resilience.[17] DERs have shown potential for providing reliable and secure access to all kinds of consumers, including households, farmers, small businesses, and large industrial and commercial consumers. Deployment of such systems could be accelerated with appropriate and timely policies, regulations, and incentives to ensure clean, affordable, and reliable energy access for all, as envisioned in Sustainable Development Goal 7. Systems such as mini-grids could become cost-effective if planned for a broader set of consumers (including small enterprises) and scaled up by integrating them with productive end-use systems. Although the government is implementing policies to ensure that DERs become part of the energy mix, much more still needs to be done to unlock investment and financing and overcome regulatory and administrative hurdles.

Policy measures with sector coupling. There are significant secondary benefits from reliable access to energy in sectors such as health and agriculture, as was discussed in the section on resilience and socioeconomic benefits. During the pandemic, DERs have proved to be resilient for rural healthcare centers. Further, urban hospitals are charged with high commercial prices by electricity utilities and have the potential to use rooftop solar PV to reduce costs and ensure reliable supply. The estimated rooftop solar PV potential for public healthcare systems in India is approximately 450 MW, and cumulative savings on electricity for state government could be around $214 million, along with a cumulative reduction in greenhouse gas emissions of 17 million tons of CO_2.[18] Realizing this potential would require investments from the healthcare sector. The World Health Organization has also emphasized the potential of decentralized RE solutions to expand health facility access to cost-effective and reliable electricity. Hence, to realize the immense

16 IEA, "Renewables Integration in India," 2021, https://www.iea.org/reports/renewables-integration-in-india.

17 Prasanth Regy et al., *Turning Around the Power Distribution Sector: Learnings and Best Practices from Reforms* (New Delhi: NITI Aayog, RMI, and RMI India, 2021), https://www.niti.gov.in/sites/default/files/2021-08/Electricity-Distribution-Report_030821.pdf.

18 Manu Strivastava and Amit Jain, "CEO Niti Aayog launches Sun's Blessings and Health (SuBaH)," https://www.linkedin.com/pulse/ceo-niti-aayog-launches-suns-blessings-health-subah-manu-srivastava?trk=articles_directory.

potential of DERs for the healthcare sector, and even for other sectors such as agriculture, India could consider designing suitable policy measures that direct financing, investment, and incentives to allow sector coupling and thereby more effectively utilize resources.

Investment and financing. The Indian government is promoting DERs largely through provision of capital subsidies for rooftop solar PV systems. Concessional funding and lines of credit from bilateral and multilateral banks, along with domestic funding from local banks, are already in place. India could further explore setting up dedicated green banks to identify DERs and other such technologies for priority lending with low-interest loans. In the case of rooftop solar PV, increasing third-party ownership and aggregation of projects into a larger transaction size could help unlock investment and improve debt-financing options, especially for small and medium-sized enterprises. Appropriate remuneration policies and utility-led business models for improving procurement could further mobilize financing for such DERs. There is an opportunity to tap into investments from regional cooperation—for example, India has extended a concessional $100 million line of credit to Sri Lanka for the development of rooftop solar PV projects.

Recovery from the Covid-19 pandemic and distribution sector reforms. As countries are developing strategies to "build back better" from the Covid-19 pandemic, India also needs to ensure that the recovery is socially and economically sustainable for all in the energy value chain. The recovery from the pandemic offers opportunities for India to utilize the immense potential of DERs to support local jobs and employment and for reskilling during the transition to cleaner and more reliable energy sources. Indian distribution companies were hit badly as the electricity demand from their premium commercial and industrial consumers dropped sharply during the lockdowns. These consumers, who generally pay higher prices, cross-subsidize the costs of electricity for agricultural and residential consumers. The shift to solar pumps for agriculture could significantly reduce distribution companies' power-procurement costs. At the same time, greater deployment of rooftop solar PV systems for residential consumers could bring savings on cross-subsidies to these companies. As commercial and industrial consumers shift toward more rooftop solar PV systems, distribution companies may lose revenue, but these losses could be mitigated by shifting rooftop solar PV consumers to time-of-use tariffs, as was done by California in 2016.

Digitalization and disruptive technologies. India has introduced a new scheme for modernizing the infrastructure of distribution companies and accelerating the smart-metering infrastructure. This scheme offers opportunities for these companies to take full advantage of the disruptive distributed technologies beyond rooftop solar PV to include energy storage and electric vehicles. Advanced smart-metering and digital technologies could ensure better energy accounting, increase transparency for both for consumers and utilities, and unlock demand-side flexibility for enabling higher shares of RE integration in the grid. The regulatory framework needs clear price signals and incentives to reduce peak demand, encourage the active participation of consumers in energy transitions, and maximize the benefits from a firm, affordable, and reliable power supply.

In villages, digital technologies such as remote-monitoring systems could be an important tool to help assess demand and meet the power needs of consumers. Mlinda's mini-grids in India have shown, for example, that remote-monitoring systems can reduce operating costs by $2,400 per grid per annum.[19]

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[19] International Renewable Energy Agency (IRENA), *Quality Infrastructure for Smart Mini-Grids* (Abu Dhabi: IRENA, 2020), https://sun-connect-news.org/fileadmin/DATEIEN/Dateien/New/IRENA_Smart_mini-grids_outlook_2020.pdf.

As India accelerates deployment of DERs, there is an opportunity to develop a peer-to-peer trading platform for rooftop solar PV power. This innovative mechanism would encourage the trade of clean energy within a neighborhood using blockchain technologies. In a post-pandemic world, data centers and telecom service providers, among other actors, would be expected to operate with more reliable electricity. Thus, powering such centers with distributed energy could facilitate more resilient and secure access.

The Decarbonization of India's Energy Sector: Challenges in Ratcheting Up Nationally Determined Contributions

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EXECUTIVE SUMMARY

This essay identifies the factors behind India meeting its energy-related nationally determined contributions (NDCs) in the Paris Agreement and then analyzes whether these factors will hold up as India embarks on a mission to simultaneously industrialize and decarbonize.

MAIN ARGUMENT

India is likely to meet its energy-related NDCs to decrease its carbon intensity because of pre-existing trends that have decreased energy intensity. First, the switch from biomass that has very low conversion efficiency to high-efficiency fossil fuel–based fuels enabled growth in economic activity without commensurate growth in energy consumption. Second, the shift in structural composition of growth in favor of the services sector was less energy-intensive than growth dominated by industry. Third, production and consumption processes increased technical efficiency. Fourth, India's slow pace of industrialization and the consequent low per capita energy consumption limited the increase in carbon intensity. However, the contribution from these trends toward a further increase in NDC targets may be limited. To achieve the twin goals of industrialization and decarbonization, India cannot continue to depend on inherent factors that contributed to a reduction of energy and carbon intensity in the past. Instead, it must enact clear policies that promote the production of green products and services.

POLICY IMPLICATIONS

- India needs to articulate unambiguous policies that are designed to combine industrialization with decarbonization. Export-oriented policies for production of green goods (products and services that use or produce green energy) hold the greatest potential to simultaneously achieve the goals of decarbonization and industrialization.
- Trends that contributed to lowering energy intensity in the past two decades cannot be relied on for future decarbonization, which means India will need to lean heavily on policies for increasing the share of clean energy.
- As most external funds for decarbonization are likely to take the form of investment rather than aid, policies need to prioritize clean energy–based industries where India can gain a competitive advantage over its more mature rivals.

India's nationally determined contributions (NDCs) to the Paris Agreement commit the country to reduce the emission intensity of GDP (CO_2 emissions per unit of GDP) by 33%–35% by 2030 from 2005 levels; achieve around 40% cumulative installed capacity for electric power generation from energy resources not based in fossil fuels by 2030 with the help of transfers of technology and low-cost international finance, including from the Green Climate Fund; and create an additional carbon sink of 2.5 to 3.0 billion tons of CO_2 equivalent through adding more forest and tree cover by 2030.[1]

By most authoritative accounts, India is likely to achieve the first two commitments well before 2030. The Climate Action Tracker observed that the country will overachieve its energy- and emission-related NDC targets for 2030 by a wide margin.[2] In fact, according to a study of the G-20 economies' progress toward meeting their NDCs, India (the third-largest CO_2 emitter) is among the six countries on track to achieve their NDC targets.[3]

Indian leaders are proud of meeting and exceeding their commitments to the Paris Agreement ahead of the deadline, but the NDCs set a relatively low bar that would have been achieved by 2030 even under a business-as-usual scenario. In 2015, when the Paris Agreement was formulated, the Climate Action Tracker rated India's NDC pledges as "medium," suggesting that they were in line with the effort-sharing approaches that focus on equal cumulative per person emissions. But it also observed that they were at the least ambitious end of what would be a fair contribution. The tracker commented that this was not consistent with limiting warming to below 2°C unless other countries make much deeper reductions and comparably greater effort.[4] India was deliberately not ambitious in setting its NDCs because the government did not aim for a "temperature goal" but a "best effort" path keeping in mind the development imperatives of the country.[5]

The next section identifies factors behind India achieving its NDC pledges. This is followed by a discussion of the challenges posed by the country's continued dependence on the same factors for further decarbonization of its energy sector. The closing section then considers policy pathways that would allow India to industrialize while simultaneously decarbonizing its economy.

Factors Influencing Nationally Determined Contributions

Although India has indeed made significant progress on achieving its NDCs and building out clean energy capacity, there are two key factors that can greatly influence future progress to meet

1 Government of India, "India's Intended Nationally Determined Contribution: Working Towards Climate Justice," 2015, https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/India%20First/INDIA%20INDC%20TO%20UNFCCC.pdf.

2 Climate Action Tracker, "India," https://climateactiontracker.org/countries/india.

3 To put India's progress in perspective, a comparison with China and the United States, the largest- and second-largest emitters is warranted. Some studies conclude that China is on track to meet its NDCs, while others say that there is only a 16% probability that it will hit the target. However, the Climate Action Tracker categorically states that China is on track to achieve its NDC goals by 2030 and is likely to overachieve its goals for carbon intensity and non–fossil fuel share. In the case of the United States, most studies conclude that its current policy trajectory is more than 15% higher than its average unconditional NDC target, but one recent study puts the probability of the United States achieving the target at less than 2%. See Michael den Elzen et al., "Are the G20 Economies Making Enough Progress to Meet their NDC Targets?" *Energy Policy* 126 (2019): 238–50, https://www.sciencedirect.com/science/article/pii/S030142151830750X.

4 Janet Arlene Amponin and James Warren Evans "Assessing the Intended Nationally Determined Contributions of ADB Developing Members," Asian Development Bank, August 2016, https://www.adb.org/publications/assessing-indc-adb-developing-members.

5 Ministry of Finance (India), "Report of the Sub-Committee for the Assessment of the Financial Requirements for Implementing India's Nationally Determined Contribution (NDC)," June 2020, https://www.dea.gov.in/sites/default/files/Sub%20Committee%20Report%20Final.pdf; and Government of India, "India's Intended Nationally Determined Contribution," 1.

and strengthen climate targets: emission intensity and the overall percentage of low-carbon fuels used.

Reduction in Emission Intensity

Between 1970 and 1990, commercial energy consumption in India grew at an average of 5.7%, while the economy grew at an average of 4.3%.[6] In this period, substantially greater infrastructure construction, especially for power generation, increased industrial energy consumption. In addition, investment in electrical equipment and motor cars increased middle-class household electricity, petroleum, and gas consumption. These developments contributed to a rise in CO_2 emission intensity. However, since the early 1990s, when India partially opened its economy, the CO_2 emission intensity has followed a declining trend (**Figure 1**).

Between 1990 and 2019, India's GDP increased more than sixfold, while total final energy consumption increased only by a factor of 2.5 (or GDP grew more than twice as fast as energy consumption).[7] This means that India has required less energy to produce an additional unit of economic output over the years. According to government data, its CO_2 intensity in 2021 was 28% lower than its CO_2 intensity in 2005.[8] The International Energy Agency (IEA) observes that a structural shift away from traditional biomass (e.g., firewood and animal dung) as fuel for cooking in Indian households was one of the key drivers behind the increase in energy-use efficiency.[9] The switch from biomass that has a very low conversion efficiency (5%–10%) to high-efficiency petroleum-based fuels enabled growth in economic activity without commensurate growth in energy consumption. According to the IEA, the decline in the share of biomass in India's energy basket was responsible for 60% of the decline in energy intensity.

The second driver of the improvement in energy intensity was the shift in the structural composition of growth in favor of the services sector, which is less energy-intensive than growth dominated by industry.[10] Nearly 90% of total value-added growth in India in 1990–2017 came from sectors in the lowest energy-intensity category, including, but not limited to, large retail service sectors, business, and financial services.[11]

The third driver was technical efficiency of production and consumption processes. Relatively high energy prices, price sensitivity among consumers, and a young capital stock contributed to technical efficiency in energy use.[12] The general wave of economic efficiency improvements that occurred after liberalization in the early 1990s also contributed to the improvement in technical efficiency in manufacturing processes in India.

The fourth factor—a rather perverse one—is India's slow pace of industrialization and the consequent low energy consumption per capita that has limited the increase in carbon intensity.

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6 Céline Guivarch and Sandrine Mathy, "Energy-GDP Decoupling in a Second-Best World: Case Study on India," *Climatic Change* 113, no. 2 (2012): 339–56.

7 International Energy Agency, "India Energy Outlook 2021," February 2021, https://iea.blob.core.windows.net/assets/1de6d91e-e23f-4e02-b1fb-51fdd6283b22/India_Energy_Outlook_2021.pdf.

8 "Significant Progress Made by India in Meeting Its NDC Targets While Staying Committed to Meeting its Climate Goals under the Paris Agreement: Shri RK Singh," Ministry of Power (India), Press Release, July 23, 2021, https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1738317.

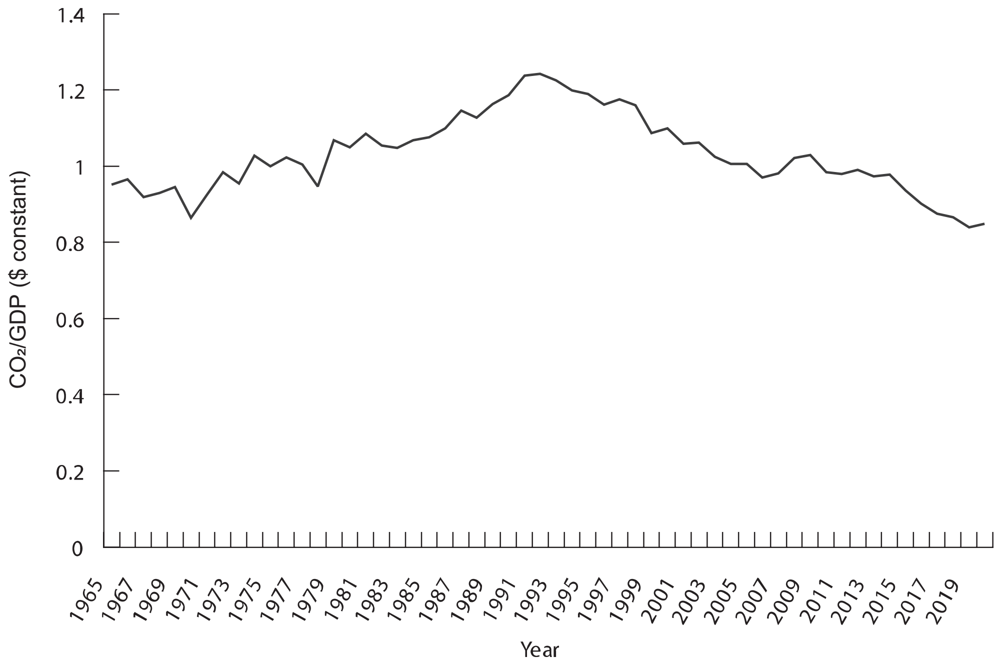
9 IEA, "India Energy Outlook 2021."

10 Jonas Karstensen et al., "Key Drivers of Indian Greenhouse Gas Emissions," *Economic and Political Weekly* 55, no. 15 (2020): 47.

11 World Bank, "India Development Update, March 2018: India's Growth Story," March 2018, https://openknowledge.worldbank.org/handle/10986/29515.

12 Shyamasree Dasgupta, Shivam Satija, and Prateek Gauba, "Energy Use Behaviour of Manufacturing Industries in India: An Analysis Using KLEMS Framework," *Journal of Industrial Statistics* 6, no. 1 (2017): 72–88, http://mospi.nic.in/sites/default/files/reports_and_publication/NSS_Journals/jr5_6_1March2017.pdf.

FIGURE 1 India's change in CO_2 intensity, 1965–2020



SOURCE: BP, "Statistical Review of World Energy," 2021; and World Bank, DataBank.

In 2019–20, India generated 1,381 terawatt hours of electricity.[13] Divided equally between a population of over 1.395 billion, that amounts to electricity consumption of just under 1,000 kilowatt hours (kWh) per person, which is lower than the world average of 3,316 kWh in 2020.[14] India is the only country in the G-20 that has energy consumption below the world average. Low energy consumption, or more accurately low incomes that limit energy consumption at the household level, has meant a poor quality of life for millions of households, especially those in rural areas. India's late start in industrializing is seen as an opportunity to leapfrog into infrastructure for a green low-carbon economy, given that much of the infrastructure that will exist in 2050 is yet to be built.[15] But choosing new green technology means phasing out old technology, which can be expensive. For example, the cost of the phaseout of coal in Germany is 40 billion euros.[16] In 2020, Germany's per capita coal consumption was almost twice that of India and its per person income almost 25 times India's level.[17]

13 These calculations are according to data available on August 20, 2021. For India's financial year from March 2019 to April 2020, see Ministry of Power (India), "Power Sector at a Glance: All India," https://powermin.gov.in/en/content/power-sector-glance-all-india.

14 These calculations are according to data available on August 20, 2021. "Per Capita Electricity Use," Our World in Data, https://ourworldindata.org/grapher/per-capita-electricity-consumption?tab=table.

15 Arthur A. van Benthem, "Energy Leapfrogging," *Journal of the Association of Environmental and Resource Economists* 2, no. 1 (2015): 93–132.

16 Pao-Yu Oei et al., "Coal Phase-Out in Germany: Implications and Policies for Affected Regions," *Energy* 196 (2020).

17 BP, "Statistical Review of World Energy 2021," July 2021, https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2021-full-report.pdf; and World Bank, "Per Person Income in Current USD, 2020," https://data.worldbank.org/indicator/NY.GDP.PCAP.CD.

Increase in Share of Low-Carbon Fuels

As of September 2021, India's non–fossil fuel power-generating capacity of 154,825 megawatts (MW) was 39.8% of the total installed power-generating capacity of 388,848 MW (see **Figure 2**).[18] There is no doubt that the NDC target of 40% of generating capacity for non-fossil fuel will be achieved almost a decade ahead of the deadline. New renewable energy (RE) capacity (excluding nuclear and hydropower) accounted for over 26% of total power-generation capacity, the second-largest share after coal. Solar, wind, small hydropower, biomass, and other sources accounted for over 65% of capacity not based in fossil fuel, while large hydropower accounted for 30% and nuclear for just over 4%. India will achieve these targets despite the fact that it may not achieve the target of 175 gigawatts (GW) of installed RE capacity (excluding large hydropower) by December 2022.[19]

The increase in RE share is mostly policy-driven through incentives for solar (and other renewable sources) in the form of feed-in tariffs, accelerated depreciation, generation-based incentives, renewable purchase obligations, waivers of interstate transmission charges, and income tax breaks.[20] Apart from these, the "must run" status under the Central Electricity Regulatory Commission's 2010 regulations has been critical to the growth of solar photovoltaic (PV) power generation in India. Must-run status implies that solar generation cannot be curtailed for factors other than grid safety or safety of equipment or personnel. Under the grid code, curtailment (reduction in power offtake) is allowed only for natural reasons, such as grid unavailability or failure to ensure grid stability. This means that while scheduling generating stations in a region, system operators are required to aim toward full utilization of available solar energy.[21]

Though RE accounted for the second-largest generation capacity share, it accounted for less than 10% of generation in 2020–21 (from April 2020 to March 2021, India's financial year), equaling hydropower generation that has only half the capacity of RE.[22] Not surprisingly, coal accounted for 54% of capacity but contributed over 79% of generation in 2020–21. In terms of specific generation or power generated per unit of capacity that represents economic efficiency, nuclear power was the most efficient, with a score over 6, while RE power was the least efficient, with a score less than 1 in 2020–21.[23]

As in the case of carbon intensity, the NDC goal for increasing the share of generating capacity not based in fossil fuels was well within the scope of business-as-usual policies that predate the NDCs. The Jawaharlal Nehru National Solar Mission (now the National Solar Mission), which was inaugurated in January 2010, five years before the Paris Agreement, had set a target of 20 GW of solar PV by 2022. In 2015, the 2022 target for solar PV was increased to 100 GW and the overall target for RE capacity was increased to 175 GW by the new government led by Narendra Modi that took charge in 2014.[24]

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18 Ministry of Power (India), "Installed Capacity Report," September 30, 2021, https://cea.nic.in/installed-capacity-report/?lang=en.

19 "Starred Question No: 437," Ministry of New and Renewable Energy (India), Press Release, March 25, 2021, http://164.100.47.194/Loksabha/Questions/QResult15.aspx?qref=23909&lsno=17.

20 Ministry of New and Renewable Energy (India), "Solar Policy and Guidelines," https://mnre.gov.in/Solar/policy-and-guidelines; and Ministry of New and Renewable Energy (India), "Wind Policy and Guidelines," https://mnre.gov.in/Wind/policy-and-guidelines.

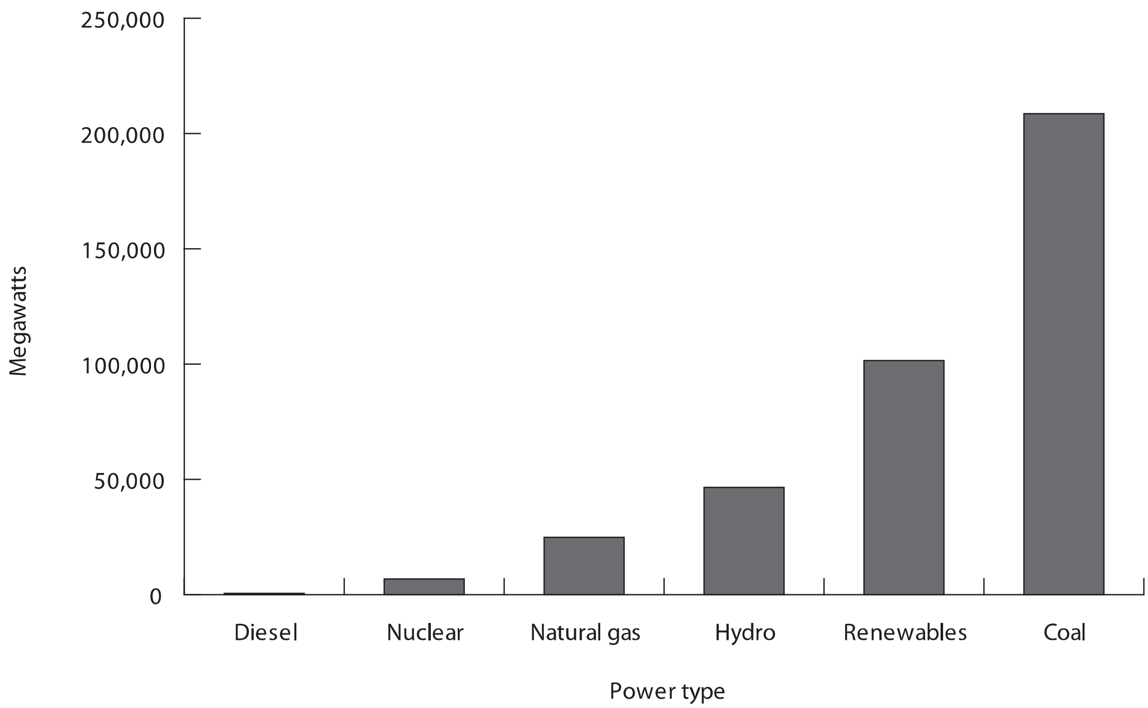
21 Ministry of New and Renewable Energy (India), "MNRE: Year End Review 2020," December 31, 2020, https://pib.gov.in/Pressreleaseshare.aspx?PRID=1685046.

22 Ministry of Power (India), "Power Sector at a Glance."

23 Ministry of Power (India), "Growth of Electricity Sector in India 1947–2020," October 2020, https://cea.nic.in/wp-content/uploads/pdm/2020/12/growth_2020.pdf.

24 "Revision of Cumulative Targets under National Solar Mission from 20,000 MW by 2021–22 to 1,00,000 MW: India Surging Ahead in the Field of Green Energy—100 GW Solar Scale-Up Plan," Ministry of New and Renewable Energy (India), Press Release, June 17, 2015, https://pib.gov.in/newsite/PrintRelease.aspx?relid=122567.

FIGURE 2 Power-generation capacity, September 2021



SOURCE: Central Electricity Authority (India).

Ratcheting Up the Nationally Determined Contributions

With these factors in mind, the most recent report from the Climate Action Tracker that rates India's climate targets and policies as "highly insufficient," indicating that India's policies and commitments are not consistent with the Paris Agreement's 1.5°C temperature limit, suggests additional urgency for policymakers.[25] Using strong language, the report declares that India must increase its unconditional NDC target to significantly reduce the speed of emission growth and set an ambitious conditional target to curb its dependence on fossil fuels and begin the shift to a net-zero economy with international support.

According to reports from the Indian government, the rate of decarbonization will improve even under current policies. The Ministry of Finance observes that under the "current goals" scenario, a reduction in emission intensity of GDP by 58%–59% from 2005 levels in constant dollar terms by 2030 is possible.[26] India's current goals include 175 GW of RE by 2022 and 450 GW of RE by 2030. Under an "aspirational goals" scenario, a reduction of 60%–61% from 2005 levels is achievable by 2030. The Ministry of Finance has projected that 50% of power generation could come from non-fossil fuels (RE, nuclear, and hydropower) under the current goals scenario, which would increase to 56% under the aspirational goals scenario by 2030.

25 Climate Action Tracker, "India."

26 Ministry of Finance (India), "Report of the Sub-Committee," 2.

Globally, cumulative emissions in 2100 are expected to be 2,083 gigatons (Gt) CO_2 if Paris Agreement commitments are met. To have a 50% chance of limiting warming to 2°C, cumulative emissions would need to be reduced further to 1,579 Gt CO_2.[27] Assuming a constant rate of annual decline in global emissions, this would require an annual rate of decline of 1% to reach the NDCs and 1.8% to have a 50% chance of staying under 2°C. While the average rate of decline would need to increase by 80%, this does not mean that the NDCs would need to increase by as much. According to detailed country-wide analysis, the needed increase in the NDCs for the largest emitters is 7% for China, 38% for the United States, and 55% for India.[28] This means that India needs to increase its 30% target for reducing carbon intensity to over 46%, which can be achieved even under the current goals scenario.

According to projections by the Central Electricity Authority for the optimal mix of generation capacity for 2030, power-generation capacity not based in fossil fuel is likely to increase to roughly 64% of a total installed capacity of 817,254 MW.[29] Solar power will have the largest power-generation capacity of over 280 GW, accounting for over 34% of power-generation capacity in 2030, while coal-based power generation of 266 GW will account for 32% of total installed capacity. The Central Electricity Authority's analysis takes the draft national energy policy's projection of a capacity of 476,431 MW for 2021–22 as its base. The draft national energy policy estimated a capacity of 100 GW from solar alone in 2021–22. As of September 2021, the capacity of grid-connected solar power generation was 46,275 MW, which suggests that installation of solar capacity may be slower than anticipated.[30] There is, however, skepticism about achieving these targets from both within and outside the government. A report of the government-appointed Standing Committee on Energy released in March 2021 noted that in over a decade only 39 GW of solar energy capacity (46 GW as of September 2021) had been installed in the country, and the targets for solar energy capacity by 2022 are highly unlikely to be achieved.[31] Agencies outside the government that follow RE installation in India concur.[32] But the government is optimistic that the target of 175 GW for RE capacity by 2022 will be met. According to its assessment, over 50 GW of RE capacity is under various stages of implementation and a capacity of over 27 GW is under various stages of bidding, which adds up to 177 GW of capacity.

Most computerized simulations (including those of the Indian government) conclude that achieving high targets for RE and accelerating the pace of the decarbonization process are within the realm of technological possibility. But technology leapfrogging cannot be achieved without the necessary economic, social, and political conditions for radical change from fossil fuels to clean

27 Peiran R. Liu and Adrian E. Raftery, "Country-Based Rate of Emissions Reductions Should Increase by 80% Beyond NDCs to Meet the 2°C Target," *Communications Earth and Environment* 2 (2021): 1.

28 Ibid.

29 Ministry of Power (India), "Report on the Optimal Generation Capacity Mix for 2029–30," January 2020, https://cea.nic.in/wp-content/uploads/irp/2020/12/Optimal_mix_report_2029-30_FINAL.pdf#:~:text=Optimal%20generation%20capacity%20mix%20is%20a%20study%20primarily,the%20year%202029-30%20as%20per%2019thElectric%20Power%20Survey.

30 Ministry of Power (India), "Installed Capacity Report."

31 Ministry of New and Renewable Energy (India), "Action Plan for Achievement of 175-Gigawatt Renewable Energy Target," Report of the Standing Committee on Energy, March 19, 2021, http://www.indiaenvironmentportal.org.in/files/file/Action%20Plan%20for%20achievement%20of%20renewable%20energy.pdf.

32 "India Renewables Outlook 2024," Bridge to India Research, https://bridgetoindia.com/report/india-renewables-outlook-2024; and Nandini Jhalani, "With 80 GW to Go, India Looks Set to Miss 2022 Renewable Energy Target," Wire Science, June 5, 2021, https://science.thewire.in/environment/with-80-gw-to-go-india-looks-set-to-miss-2022-renewable-energy-target.

technologies.[33] These critical challenges are not captured by quantitative models, especially in the context of a country like India that is attempting to industrialize while also decarbonizing.

Challenges

The first obvious challenge is raising the funds required to achieve India's NDC and other targets through technology. The projected cumulative cost of increasing decarbonization goals is estimated by the Ministry of Finance to be between 245 and 280 trillion rupees ($3.2–$3.7 trillion) in 2018–30 in the current and aspirational goals scenarios.[34] Although the Ministry of Finance observes that more than half this amount will be raised domestically, the rest will need to come from external sources. External funding has been far below expectations so far.[35]

The second challenge is the shift away from biomass to modern cooking fuels by households that reduced carbon intensity in the last few decades. Consumption of fuels like liquid petroleum gas and grid-based electricity by poor rural households is relatively low now, but it could rise substantially in the future if the pace of urbanization accelerates along with a substantial rise in household income. This would dramatically increase consumption of fossil fuels, which would in turn mean an increase in emissions.

The third challenge raises a broader question about India's economic trajectory and whether the country's decarbonization goals are consistent with its recent industrial policies such as "Make in India" and "self-reliance." The case of the Indian solar sector illustrates the contradiction. India, which imports over 90% of solar components, is now a promising export market for the world's leading solar cell and panel manufacturers.[36] This development of the solar sector has contributed to rapid scaling of installed capacity and a reduction of tariffs, but it has come at the cost of the domestic manufacturing sector. By most in-depth analysis, the possibility of resurgence in solar manufacturing remains limited, notwithstanding the safeguard duty on imports and the manufacturing-linked solar incentive program.[37] Enthusiasm for solar capacity expansion and tariff reductions increased imports of solar equipment. It is unlikely that the failure to integrate manufacturing priorities within the solar mission can be corrected at this late stage, given that China and other East Asian economies already host competitive and mature solar manufacturing industries. Within the Indian government there appears to be some concern over entering the mature industry of solar equipment manufacturing. For example, the CEO of NITI Aayog, the in-house think tank of the government, cautioned that India must resist the temptation to enter the "sunset" industry of solar cell and battery manufacturing and focus on new avenues such as the production of green hydrogen.[38]

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[33] Richard Perkins, "Environmental Leapfrogging in Developing Countries: A Critical Assessment and Reconstruction," *Natural Resources Forum* 27 (2003): 177–88.

[34] Ministry of Finance (India), "Report of the Sub-Committee," 2.

[35] Kate Abnett, "Lukewarm: Rich States Set to Fall Short of $100 Bln Climate Funding Goal," Reuters, September 17, 2021, https://www.reuters.com/business/sustainable-business/lukewarm-rich-states-set-fall-short-100-bln-climate-funding-goal-2021-09-17.

[36] Mayank Aggarwal, "A Long Road to 2030 for India's Import-Heavy Solar Power Sector," Mongabay, May 21, 2021, https://india.mongabay.com/2021/05/graphs-a-long-road-to-2030-for-indias-import-heavy-solar-power-sector.

[37] Pritish Behuria, "The Politics of Late Late Development in Renewable Energy Sectors: Dependency and Contradictory Tensions in India's National Solar Mission," *World Development* 126 (2020), https://www.sciencedirect.com/science/article/pii/S0305750X19303754.

[38] "India Should Focus on Sunrise Sectors to Stay Competitive: NITI Aayog CEO," *Business Standard*, December 12, 2020, https://www.business-standard.com/article/pti-stories/govt-taking-steps-to-make-india-competitive-in-global-economy-focus-on-sunrise-sectors-must-kant-120121200391_1.html.

A related concern is that manufacturing-led growth is likely to be more energy-intensive than the service-led growth that was among the drivers of falling carbon intensity in the last few decades. But service-led growth was also “jobless growth” in the sense that it did not create jobs for low-skilled workers who dominate the labor force in India.[39] This is an important issue from the perspective of making a just transition toward decarbonization. Decarbonization may progress at the cost of manufacturing-led economic growth, which means continuing the slow pace of income growth and poor quality of life for people in the lowest economic and social strata of India.

The case of China is illustrative. In 1980, its per capita GDP was two-thirds that of India. Four decades later, China’s per capita GDP is more than five times that of India. Between 1978 and 2018, China’s energy-related CO_2 emissions increased sixfold, and 176% of the overall change in energy-related emissions was driven by an increase in per capita GDP that was closely corelated with per capita energy consumption.[40] China’s energy consumption and CO_2 emissions have increased by an annual average of over 9% since 2001, when its growth took off.

India’s plans for rapid industrialization are not coherent, but the country is unlikely to follow China’s path. A statement from within the government acknowledges that “India cannot become the next factory of the world by copying China.”[41] But it is unclear what alternative approach the government can take to achieve the goal set in 2019 of making India a $5 trillion economy by 2024–25, which will require an annual growth of 8%.[42] India has announced plans to invest 100 trillion rupees (over $1.3 trillion) in infrastructure, but it will need to follow a path for which there is no precedent.[43] This radically new path must promote economic growth, generate employment, improve energy consumption, and enhance quality of life for millions of people while also limiting CO_2 emissions.

Next Steps

As a late industrializer, India faces the unprecedented challenge of industrializing while also trying to decarbonize. This could, however, be turned into an opportunity to illustrate to the world that these seemingly contradictory goals can be achieved simultaneously. Toward this end, the most important step is to articulate unambiguous policies that are designed to pivot industrialization policies toward production of export-oriented green goods (products and services that use or produce green energy), which will enable the country to decarbonize simultaneously. The structural trends that were behind India’s achievement of its NDCs are not likely to make a further contribution toward decarbonization. This will heighten the reliance on policies that seek to increase the share of RE for further decarbonization.

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39 Rashmi Banga, “Critical Issues in India’s Service Led Growth,” Indian Council for Research on International Economic Relations, October 2005, http://www.icrier.org/pdf/WP171.pdf.

40 Xiaoqi Zheng et al., “Drivers of Change in China’s Energy-Related CO_2 Emissions,” *Proceedings of the National Academy of Sciences* 117, no. 1 (2020), http://www.pnas.org/content/117/1/29.

41 “India Cannot Become Next Factory of World by Copying China, Says Niti Aayog CEO Amitabh Kant,” *Financial Express*, August 12, 2021, https://www.financialexpress.com/economy/india-cannot-become-next-factory-of-world-by-copying-china-says-niti-aayog-ceo-amitabh-kant/2309577.

42 Ministry of Finance (India), “Shifting Gears: Private Investment as the Key Driver of Growth, Jobs, Exports and Demand,” in *Economic Survey* 2018–19, vol. 1 (New Delhi, 2019), https://www.indiabudget.gov.in/budget2019-20/economicsurvey/doc/vol1chapter/echap01_vol1.pdf.

43 Aftab Ahmed, “Modi Says India Will Soon Unveil $1.35 Trillion Infrastructure Plan,” Reuters, August 15, 2021, https://www.reuters.com/world/india/indias-modi-says-135-trillion-infrastructure-plan-be-unveiled-soon-2021-08-15.

The success of these initiatives will critically depend on India's ability to attract the necessary funding. As funds for decarbonization increasingly take the form of investment rather than aid, India will need to demonstrate consistency and long-term commitment in its policies and focus on the production of green goods and services, where the country has a clear competitive advantage over its rivals.

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