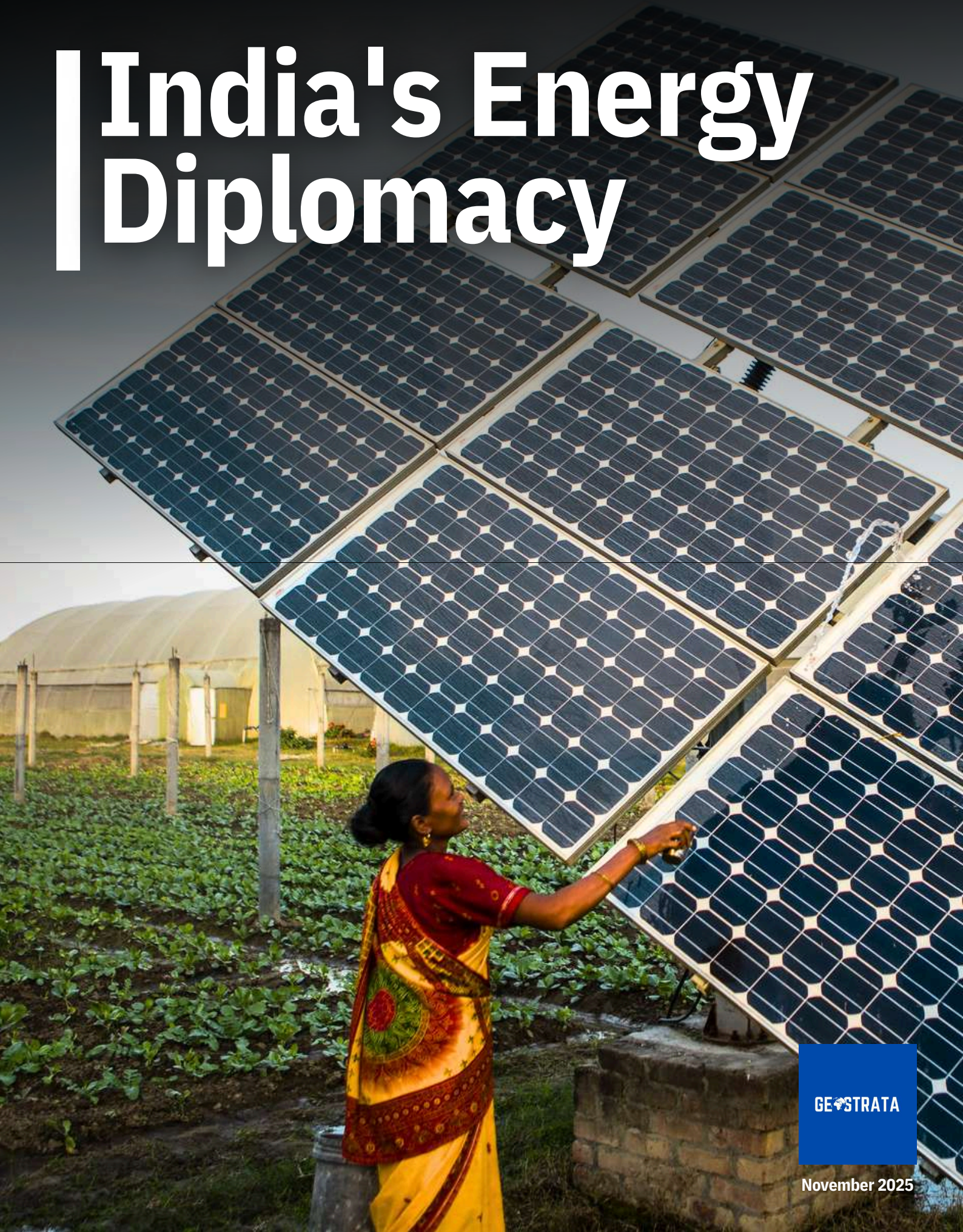
By Centre for Diplomacy and Innovation

India's Energy Diplomacy



GEOSTRATA

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By Centre for Diplomacy
and Innovation

GEOSTRATA

India's Energy Diplomacy

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Executive Summary

India’s energy diplomacy drives its transition towards a more sustainable and secure energy future.

India’s energy diplomacy drives its transition towards a more sustainable and secure energy future. As global energy demands rise and environmental concerns intensify, India is leveraging international partnerships, innovative technologies, and policy reforms to position itself as a leader in renewable energy. The nation’s approach focuses on fostering global collaboration, advancing technological development, and enhancing domestic capacity to achieve energy security while addressing climate change.

This report explores India’s integrated energy strategy, leveraging partnerships with international organisations, technology leaders, and emerging markets to drive innovation, enhance energy security, and promote economic development. By highlighting key initiatives, from policy reforms and technology transfers to capacity building and industrial scaling, the report aims to demonstrate how India addresses critical challenges while creating new opportunities in renewable energy.

India’s vision transcends domestic ambitions, aiming to serve as a global model for inclusive and sustainable energy transitions. By fostering international cooperation and leveraging its unique geopolitical position, India ensures its energy future and contributes to the fight against climate change. This approach represents India’s commitment to a renewable-powered future, balancing environmental responsibility with economic progress.

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India's Energy Diplomacy

As global energy demands rise and environmental concerns intensify, India is leveraging international partnerships, innovative technologies, and policy reforms to position itself as a leader in renewable energy.

Biofuels Energy

Biofuels provide opportunities for reducing reliance on fossil fuels and climate mitigation while also representing the possibility of substituting between two essential but very different commodities: food and energy.

In the current geopolitical landscape, growing concerns regarding dependence on fuel imports and environmental degradation have prompted the pursuit of alternative fuels that offer enhanced environmental sustainability and are economically competitive with fossil fuels. This has envisioned the strategic role of biofuels in the global energy basket.

Biofuels provide opportunities for reducing reliance on fossil fuels and climate mitigation while also representing the possibility of substituting between two essential but very different commodities: food and energy. The diversion of agricultural resources to energy production has implications for food production that are of special concern to developing countries whose expenditure patterns are most food-intensive.

Biofuel, particularly in high petroleum-importing countries, provides means to rapid innovation to reduce greenhouse gas (GHG) emissions, lower dependence on the import of crude oil, achieve foreign exchange savings, provide better remuneration for the farmers, as well as address growing environment issues owing to the use of fossil fuels and burning of biomass.

Biofuel further aids in addressing challenges of waste management helps in agri-residues management, and, on a far-fetched scale, stimulates a new agribusiness energy industry in high-income economies with more energy-intensive expenditures. This comprehensive outlook delineates this part of India's energy diplomacy on achieving energy security and offers recommendations for the enhanced utilisation of biofuels.

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INDIA'S ENERGY DIPLOMACY

India's energy diplomacy is focused on sustaining and promoting energy engagements with hydrocarbon-rich countries and prominent international organisations dealing with energy matters to secure India's burgeoning energy needs. Energy collaboration has remained essential to bilateral engagements with India's traditional energy partners and newly emerging energy suppliers. India's relationship with its suppliers, such as the UAE, the USA and Russia, has transformed into a strategic partnership for mutual investments.

Through its diplomatic channel, India has secured support for its refiners in terms of uninterrupted and timely supply of crude oil while geographically diversifying and widening its oil and gas sourcing, including the acquisition of E&P assets by Indian PSUs, which has led to the launching of initiatives to promote building energy corridors and energy bridges.

Meanwhile, re-negotiating long-term oil and LNG arrangements to reflect the changing energy prices has developed close linkages as India leverages its relationship and huge hydrocarbon needs with multilateral energy organisations such as OPEC, IEF and IEA. In addition, the Global Biofuels Alliance (GBA), a multi-stakeholder alliance of governments, international organisations and industries, an initiative by India as the G20 Chair, brings together the biggest consumers and producers of biofuels to drive the development and deployment of biofuels.

The Alliance intends to expedite the global uptake of biofuels by facilitating capacity-building exercises across the value chain, technical support for national programs, promoting the sharing of policy lessons and technology advancements and intensifying the utilisation of sustainable biofuels through the participation of a broad spectrum of stakeholders.

This translates into an increased focus on collaboration and providing additional opportunities to Indian industries by exporting technology and equipment. It will also help accelerate India's existing biofuels programs such as PM-JIVAN Yojna, SATAT, and GOBARdhan scheme, thereby contributing to increased farmers' income, creating jobs and overall development of the Indian ecosystem.

Energy collaboration has remained essential to bilateral engagements with India’s traditional energy partners and newly emerging energy suppliers.

As part of India’s energy diplomacy strategy, India is working to become a gas-based economy by increasing the share of natural gas in India’s energy mix from 6% to 15% by 2030, for which the IEA and the Ministry of Petroleum and Natural Gas have organised collaborative activities on building a Gas-Based Economy in India.

India’s new biofuels policy, announced in 2018, targets bioethanol blending in gasoline of up to 10% in 2022 and 20% in 2030 and plans to construct 12 biorefineries. All these initiatives underscore the rapid growth of the biofuel sector in India. However, detailed estimates vary across scenarios and assumptions; consensus exists on its expanding significance globally.

RECOMMENDATIONS

India has significant potential to expand its modern bioenergy sector to optimise production costs further and improve biofuels' commercial viability.

1. Enhanced International Collaboration:

India should leverage multilateral mechanisms like the Technology Collaboration Programme (TCP) and partnerships under Mission Innovation (MI) to adapt advanced biofuel technologies to Indian needs. Participation in initiatives like the Bioenergy TCP and Sustainable Biofuels Challenge demonstrates India's capacity to enhance domestic innovation.

This further can be improved by strengthening bilateral partnerships with nations excelling in biofuel innovation, including the USA, Sweden, and Brazil. With the US-India Strategic Clean Energy Partnership, which was designed to promote sustainable biofuel production and facilitate public-private dialogue, more significant efforts could be put in that drive the US-India Public-Private Biofuel Task Force and share information and policy development inputs and identify research and deployment projects for mutual benefit.

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2. Strengthen Industry-Academia Ties:

Public research institutes, academic institutions, and private enterprises should collaborate to accelerate innovation and investment in biofuel technologies. Policies should address gaps in scaling emerging energy technologies, ensuring international intellectual property protection standards. This can be enhanced by increasing the number of working group projects like India and Brazil. Their Joint Working Group on Bioenergy Cooperation is leading a bilateral alliance to implement and scale up ethanol blends (E20+), flexible fuel vehicles, biodiesel, biogas/ biomethane policies, technology development and advanced fuels like SAF and ethanol; more such models can further facilitate innovation hubs and incubation centres to support startups working on biofuel projects.

3. Enhanced Technology Exchange Mechanisms:

Strengthen partnerships with countries like the USA, UK, and Sweden to foster co-development and transfer of advanced biofuel technologies. Programs like the Indo-US Joint Clean Energy Research and Development Centre should be expanded to cover biofuel-specific RD&D. Further initiatives like developing biofuel technology parks in collaboration with global partners could accelerate technology adaptation in the light of the IEA platform to coordinate multi-nation projects in biofuel research.

4. Optimise Policies for Feedstock Utilization:

Extend feedstock options under national biofuel policies to include non-food crops, damaged grains, and agricultural residues. This will bolster ethanol production and facilitate the transfer of sustainable biofuel production techniques. This can be boosted by incorporating 3G and 4G Technologies. For example, 3G biofuel is produced using non-arable land by cultivating algae, which has much higher yields and lower resource inputs than traditional energy crops.

Meanwhile, 4G biofuel is in the early concept stage, attempting to combine genomically prepared microorganisms and genetically engineered feedstock (e.g., cyanobacteria engineered to increase oil yields) thus the usage of genetically modified yeast in the fermentation process for the manufacture of biofuel. Moreover, integrating input production, such as enzymes, is a significant cost factor, especially for fermentation-based ethanol production. Integrated enzyme production and increased enzyme activity can improve process efficiencies and lower costs.

Initiatives like developing biofuel technology parks in collaboration with global partners could accelerate technology adaptation in the light of the IEA platform to coordinate multi-nation projects in biofuel research.

5. Develop Infrastructure for Waste Collection:

Support the collection of waste residues for biodiesel production to overcome feedstock shortages. Encourage waste-to-biofuel technologies, such as hydrotreated vegetable oil (HVO), which can reduce CO2 emissions and foster cost efficiency. A decentralised network for waste collection could be formulated and integrated with existing waste management initiatives, such as the Swachh Bharat Mission.

6. Scale Bio-Refinery Operations:

Support the establishment of large-scale bio-refineries using agricultural and municipal waste, such as those spearheaded by IOCL and Bharat Petroleum. Ensuring adequate capital investment and policy support for these initiatives can further increase the production capacity. Moreover, initiatives like co-processing biofuels in existing refineries can reduce capital costs and the hydrogen access burden.

Biofuels can be upgraded within FCCU using Hydrogen from DHDS. However, the blend rate into fossil streams is limited to 2-10%. Despite that, combining enzymatic hydrolysis and fermentation stages in a single unit can boost yields while lowering the capex.

7. Enhance Financial Viability:

Offer subsidies and tax incentives for greenfield and brownfield biofuel projects. Streamline government loan schemes and align ethanol and sugarcane pricing to attract private sector involvement in cost-effective biofuel manufacturing. Brownfield refineries can provide lower capex, especially for high-capacity plants. An example is ENI’s USD 300 million investment in its Gela facility over four years to set up a biorefinery of 1 Bn L capacity.

Biofuels are emerging as a critical avenue for decarbonising fossil fuels and one of the most accessible routes to climate change mitigation. They offer a compelling proposition for developing and developed countries to expedite the energy transition and balance energy security with emissions reduction.

Support the establishment of large-scale bio-refineries using agricultural and municipal waste, such as those spearheaded by IOCL and Bharat Petroleum.

Wind Energy

Wind energy will not only reshape India's power sector, but it will also steer the country's broader sustainable development trajectory.

India boasts one of the world's most promising landscapes for wind energy generation, supported by an extensive coastline exceeding 7,500 kilometres and vast onshore expanses ideal for turbine installation. India experiences strong wind currents from Kanyakumari to Gujrat, which offers immense potential for both onshore and offshore wind projects. Estimates by government-backed agencies suggest that India's onshore wind energy capacity could surpass 300 GW at a hub height of 100 metres, highlighting a vast yet not fully exploited resource. The Indian government has recognised wind energy as a cornerstone[7] of its renewable energy mix to meet domestic energy demands and curtail carbon emissions.

India has installed wind capacity exceeding 200 GW, ranking it among the top global wind energy producers. This growth is due to supportive policy measures, such as feed-in tariffs, renewable purchase obligations, and incentives for private sector involvement. As India continues to achieve its ambitious objective of attaining 500 GW of non-fossil fuel electricity capacity by 2030, wind power is poised to assume an even more critical role. Wind energy will not only reshape India's power sector, but it will also steer the country's broader sustainable development trajectory.

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INDIA'S ENERGY DIPLOMACY AROUND WIND

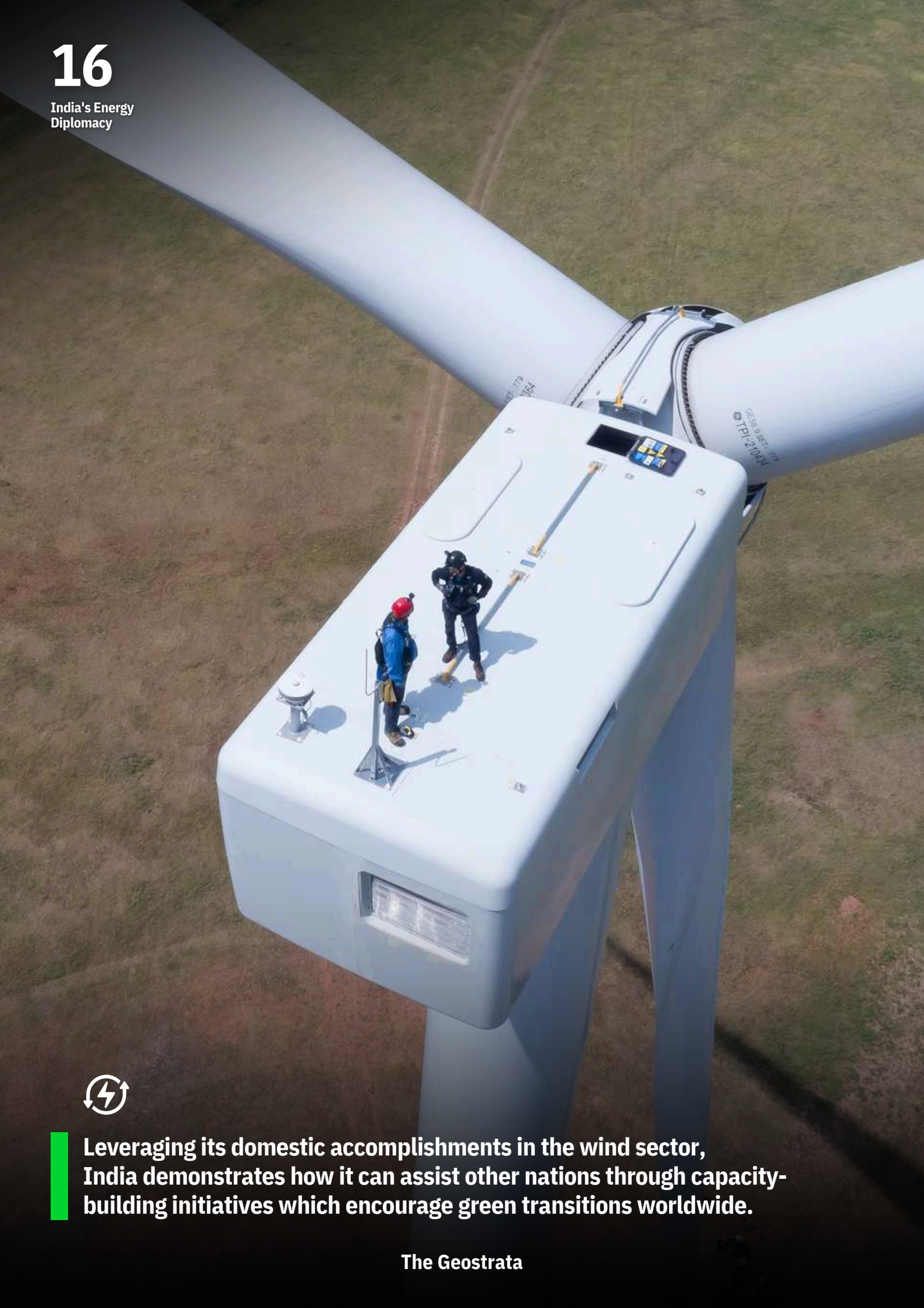
In the last decade, India has been able to keep renewable energy, notably wind power, as part of its broader energy diplomacy efforts. This includes not just the export of technical expertise and forming commercial partnerships with neighbouring nations but also the shaping of global discourse on sustainability and climate change. At international forums, India emphasises wind power as a cost-effective, scalable remedy for countries striving to cope with rising energy demands while confronting environmental challenges.

Leveraging its domestic accomplishments in the wind sector, India demonstrates how it can assist other nations through capacity-building initiatives, joint research endeavours, and technology-sharing arrangements, which encourage green transitions worldwide.

India's wind energy expertise holds the potential to unify the region in addressing shared energy concerns. Through bilateral and multilateral arrangements, India can help create cross-border power transactions, joint research efforts, and the alignment of policy frameworks. These collaborations can stabilise energy grids, lessen reliance on traditional fuels, and reinforce India's image as a frontrunner in sustainable infrastructure development.

Beyond its immediate neighbourhood, India's achievements with bodies like the International Solar Alliance (ISA) serve as a model for establishing parallel platforms centred on wind energy. As the offshore wind sector garners global attention, strategic alliances with leading turbine manufacturing nations, such as Denmark, Germany, and the United Kingdom, can unlock significant opportunities for India.

By consistently positioning wind power at the forefront of its international outreach, India can attract further investment, diversify its global partnerships, and strengthen its role as a major advocate for renewables on the world stage.



Leveraging its domestic accomplishments in the wind sector, India demonstrates how it can assist other nations through capacity-building initiatives which encourage green transitions worldwide.

RECOMMENDATIONS

1. Establish Joint "Centres of Excellence" in Wind Energy Research:

India should establish specialised "Centres of Excellence"in collaboration with eminent global research institutions from Europe, the United States, and other advanced economies. These centres would serve multiple functions: Coordinate research efforts, innovate turbine designs, and optimise how wind power can be integrated into national grids. Through jointly funded programmes,

Indian engineers and academics could collaborate with international peers to improve knowledge in aerodynamics, turbine efficiency, and the intricacies of wind mapping in regions around India. This research would encourage breakthroughs well-suited to India's diverse geographical and climatic realities, further bringing more robust and efficient wind energy solutions.

2. Promote Cross-Institutional Collaborations and Faculty Exchanges:

Beyond establishing large research hubs, India should invest in cross-institutional partnerships linking its universities and research institutes with global counterparts. Targeted faculty exchange schemes, visiting lectureships, and collaborative symposiums can encourage Indian scholars to work closely with worldwide experts in wind energy technologies.

Notably, Indian Institutes of Technology (IITs) with strong engineering specialisations could host visiting academics from institutions such as Aalborg University (Denmark), TU Delft (Netherlands), and the University of Rostock (Germany), all of which are internationally acclaimed for their wind engineering research programmes. These visiting academics would not merely deliver lectures but could guide doctoral and postdoctoral students in niche areas like offshore foundation design, superconducting generator applications, and advanced turbine aerodynamics.

Targeted faculty exchange schemes, visiting lectureships, and collaborative symposiums can encourage Indian scholars to work closely with worldwide experts in wind energy technologies.

3. Facilitate Collaborative Ventures with Global Turbine Manufacturers:

A pressing problem in expanding India's wind sector is the limited homegrown expertise in specific advanced turbine technologies, especially those applicable to offshore installations and large-scale turbine assemblies. To address this gap, the Indian government must facilitate collaborations in which foreign manufacturers such as Vestas (Denmark), Siemens Gamesa (Germany), GE Renewable Energy (United States), and Nordex (Germany) are incentivised to establish local production units and R&D centres.

Policymakers can create a favourable environment encouraging these partnerships by providing tax concessions, smoothing out land acquisition procedures, and simplifying regulatory protocols. Through joint ventures with such multinational corporations, Indian firms stand to gain practical insights into global best practices, such as covering turbine design, system integration, and operations and maintenance. Not only would this enhance local manufacturing capabilities and create new jobs, but it would also yield cost reductions through local sourcing.

4. Create a Structured Technology Transfer Framework:

India must formulate a structured technology transfer framework that clarifies intellectual property (IP) agreements, skill development pathways, and R&D investment obligations for foreign collaborators. By instituting well-defined licensing guidelines, the framework would protect both Indian and foreign stakeholders, ensuring that patented or proprietary designs are disseminated in a manner that benefits all parties.

The framework could also enforce performance targets that incentivise efficiency improvements and improved turbine reliability. Such a transparent and standardised approach to technology transfer, strengthened by policy incentives, would minimise uncertainties, bolster investor trust, and ensure that research institutions and domestic firms accrue real value.

By instituting well-defined licensing guidelines, the framework would protect both Indian and foreign stakeholders, ensuring that patented or proprietary designs are disseminated in a manner that benefits all parties.

5. Establish Wind Energy Industrial Clusters and Incubators:

To foment the rise of Indian entrepreneurs, the government should establish wind energy industrial clusters, geographically concentrated zones of component manufacturers, service providers, academic research centres, and start-up incubators. Small and medium-sized enterprises (SMEs) within these clusters could collaborate to produce essential turbine parts such as blades, towers, nacelles, and control systems. Incubation programmes would offer mentoring, seed capital, and technical assistance, reducing conventional market entry hurdles.

Over time, these industrial clusters can transform into hubs of invention, crafting region-specific solutions that cater to variable wind intensities across India. By pairing these clusters with export incentives, India stands a realistic chance of evolving into a competitive global supplier of turbine components and related services.

6. Low-Cost Financing and Green Bonds for SMEs:

It is important to note that wind energy ventures often carry high initial capital costs, with returns that materialise only in the medium to long term. To address this, the government should partner with financial institutions and international green funds to roll out low-cost financing schemes targeting wind energy SMEs. Examples include long-duration loans at reduced interest rates, partial risk guarantees, or performance-based grants. Additionally, India could embrace the issuance of green bonds earmarked for wind power projects, attracting impact investors committed to environmentally conscious portfolios.

Simultaneously, policymakers must decide to encourage commercial banks to modify their lending guidelines, which sometimes categorise renewable energy undertakings as risky. By effectively showcasing the long-term viability and scalability of wind energy, particularly in well-surveyed wind corridors, financial institutions can be persuaded to extend more competitive credit packages. This approach will open doors for smaller companies to participate in the wind market and ensure India’s wind sector grows inclusively and innovatively.

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6. Incentivise Skill Development and Workforce Training:

Creating cost-effective manufacturing capacity requires more than just investment in facilities - it also needs a skilled, future-ready workforce. India must launch comprehensive workforce training programmes with industry associations, technical universities, and local authorities.

Such programmes could centre on turbine assembly, quality assurance, operations, and maintenance, offering hands-on training to technicians and engineers with a special focus on wind-specific challenges. The government could subsidise companies that invest in workforce certification and ongoing professional development.

Vocational courses structured with these programmes will better equip graduates to step directly into operational roles at wind turbine manufacturing or maintenance facilities. Building a local talent pool diminishes reliance on international staff, streamlines operations, and raises product quality. Over time, a workforce adept at cutting-edge technologies will become India's key advantage in the global wind energy marketplace. Strong skill ecosystems also position 'Made in India' products as reliable and cost-effective, strengthening India's export prospects in renewables.


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Geothermal Energy

Through collaborative efforts, India aims to harness its geothermal potential, lessen fossil fuel reliance and achieve renewable energy and global climate goals.

India has an estimated potential of about 10,000 to 20,000 MW of geothermal energy and is still in the infancy stages of utilising this renewable energy source. More than 350 potential sites have been identified, and some promising ones have emerged in Ladakh,

Gujarat and Himachal Pradesh, but India generates practically negligible power from geothermal energy. This is mainly due to high investment costs during the initial stages, lack of technical expertise, and regulatory hurdles.

However, geothermal energy has many benefits-sustainability, reliability as a source of baseload power, and the possibility of being carbon-emissions-free; thus, it is a promising route for India to be transformed into a clean energy source and its energy security. India used energy diplomacy to meet many domestic needs. This involved several international collaborations with major geothermal partners such as the United States of America, Iceland, Indonesia and New Zealand.

Many international collaborations build domestic capacity, attract significant foreign investment and spur many joint research projects to improve technology transfer. Through collaborative efforts, India aims to harness its geothermal potential, lessen fossil fuel reliance and achieve renewable energy and global climate goals.

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INDIA'S ENERGY DIPLOMACY AROUND GEOTHERMAL ENERGY:

India's policy to close the divide between potential and reality through international cooperation is mirrored by its geothermal energy diplomacy. India has become a key partner with Iceland, which is heavily equipped with geothermal knowledge. In its MoU with Iceland, India draws attention to knowledge sharing, technical support, and joint exploration projects, particularly in Ladakh's Puga Valley, a region with enormous geothermal potential.

Collaborations between India and the United States, especially under initiatives like the Renewable Energy Technology Action Platform (RETAP), have concentrated on developing advanced geothermal technologies.

Geothermal cooperation with Asian leaders, such as Indonesia and the Philippines, is another area for regional collaboration in India. These nations are considered successful in utilising geothermal resources. Joint ventures with them facilitate the nation's drawing upon established success models in geothermal development.

Additionally, the Indian government has promoted direct foreign investment in geothermal energy through incentives and an encouraging policy framework. These diplomatic efforts are meant to help India gain access to advanced technology and train its scientists and engineers to build indigenous capacity for developing and sustaining geothermal projects independently.

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RECOMMENDATIONS

1. Advancing Policy Towards Geothermal Energy Development:

First and foremost, policy reform is necessary to create an enabling environment for geothermal energy development. India must streamline its regulatory framework, reduce bureaucratic hurdles, and provide clear guidelines for exploration and development. A dedicated geothermal policy, different from the broad renewable energy policies, would address the specific challenges of this sector. The policy should include provisions for various financial incentives, including subsidies toward exploration and drilling, the two most capital-intensive stages in geothermal development.

For example, tax breaks and reduced import duties on geothermal equipment make the sector more attractive to domestic and international investors. Another critical area is investment. The Indian government should also implement PPPs wherein the financial burden of the geothermal projects is distributed. This way, it can share the risk with private players while drawing upon their expertise and resource pool.

India could also develop a geothermal development fund to offer low-interest loans or grants to early-stage projects. This would mitigate the risks involved with exploration and attract more stakeholders into the sector. Simultaneously, international financial institutions such as the World Bank and Asian Development Bank could be approached for funding geothermal initiatives due to their commitment towards promoting sustainable energy.

A dedicated geothermal policy, different from the broad renewable energy policies, would address the specific challenges of this sector.

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2. Advancing Technological Capacity:

Technical capacity building must be the cornerstone of India's geothermal strategy. While international collaborations are essential for acquiring advanced technologies, the country needs to focus on training its human resources for long-term self-reliance.

In partnership with the world's leading institutions, geothermal research centres will serve as a knowledge exchange and innovation platform. These centres could specialise in reservoir modelling, drilling techniques, and designing geothermal plants suitable to India's geology.

Also, academic institutions in India must introduce special courses in geothermal energy so that India will have the right professionals who will spearhead the industry's growth. At present, international cooperation is prominently featured in India's geothermal diplomacy. International engagement of such nature can be built deeper.

India should represent all the global geothermal networks, like the Global Geothermal Association (GGA), to keep upgrading with the latest scientific trends and best practices. Geothermal bilateral agreements with those like Iceland and the USA have to be expanded on Indian soil with pilot-scale project development, which allows on-site application of new foreign technologies in real-time situations. Therefore, India should consider trilateral cooperation with countries with similar geothermal profiles, such as Kenya and Turkey, to approach shared challenges collectively.

Geothermal bilateral agreements with those like Iceland and the USA have to be expanded on Indian soil with pilot-scale project development, which allows on-site application of new foreign technologies in real-time situations.

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3. Research and Development For Geothermal Exploitation:

The focus areas of research and development (R&D) must be enhanced to overcome India-specific geothermal exploration and utilisation challenges. For example, most geothermal reservoirs in India lie in seismically active areas, which pose unique risks. Collaborative R&D efforts with global experts may focus on developing technologies that mitigate such risks. Besides, research needs to be directed towards low-enthalpy geothermal resources, which are much more abundant in India but less explored because of technological constraints.

4. Effective land use for Wind Energy Power Generation:

India must include geothermal energy in its larger renewable energy plan to unlock its full potential. Solar and wind energy dominate renewable space, but geothermal energy is valuable as a reliable baseload power source. Hybrid renewable energy projects combining geothermal with solar or wind could provide stable and reliable power supplies while optimising land use. For example, geothermal energy can also be used for heating and cooling purposes where electric power generation is not viable or possible, expanding its versatility.

India must include geothermal energy in its larger renewable energy plan to unlock its full potential. Solar and wind energy dominate renewable space, but geothermal energy is valuable as a reliable baseload power source.

India's renewable energy diplomacy around geothermal energy carries excellent promise but requires significant effort to break through those barriers. Targeted policy reforms, new investments, technical capacity building, and deepening international cooperation will help India unlock its full geothermal potential and make that a cornerstone of its transition to clean energy. With a strategic approach, geothermal energy could significantly contribute to the security of India's energy future, reduce its carbon footprint, and help make the country a world leader in sustainable energy innovation.

Climate finance should be an integral aspect of India's geothermal diplomacy. Geothermal power is a zero-greenhouse gas emission power source, and it aligns perfectly with global climate goals and can be sourced under international climate funds. Thus, Indiamust explore mechanisms such as the Green Climate Fund (GCF) and access financial instruments to support geothermal power projects. The funds obtained might be used for de-risking investments, capacity-building initiatives, and financing pilot projects.

Targeted policy reforms, new investments, technical capacity building, and deepening international cooperation will help India unlock its full geothermal potential and make that a cornerstone of its transitionto clean energy.

Solar Energy

Technological progress in solar energy makes it more effective and less expensive, making it a major player in transitioning toward clean power globally.

Solar energy uses the sun's power to produce electricity and thermal energy; hence, it is considered an immaculate and sustainable energy source. The leading solar technologies are photovoltaic cells, which convert light directly into electricity, and concentrating solar power systems, which use mirrors or lenses to focus sunlight, generating energy.

Solar power appeals to people because of the role it can play in mitigating climate change, reducing dependence on fossil fuels, and fostering energy independence. Technological progress in solar energy makes it more effective and less expensive, making it a major player in transitioning toward clean power globally. One needs to make strategic investments in R&D, technology transfer and capacity-building programmes that can grow the solar energy industry.

INDIA'S ENERGY DIPLOMACY AROUND WIND

Leveraging its geographical advantage and taking proactive policy measures, India has emerged as one of the global leaders in solar energy. As of 2024, the country has a solar capacity exceeding 70 GW, making it one of the top five solar-producing nations in the world.

Through such initiatives, including the National Solar Mission and the production-linked incentive (PLI) scheme, India is moving towards achieving 280 GW of solar energy by 2030. India's energy diplomacy has also been notably shaped through its stewardship over the International Solar Alliance, a coalition of 124 nations that aims to proliferate the use of solar energy globally.

ISA is multilateralism for India because it provides the member states with technology transfer, financial assistance and capacity building. India has also joined hands with countries like the United States, Australia, and France to strengthen the research, innovation, and financing mechanisms in solar energy. These partnerships are part of India's broader strategy to position itself as a hub for renewable energy technology and manufacturing.

Leveraging its geographical advantage and taking proactive policy measures, India has emerged as one of the global leaders in solar energy.

RECOMMENDATIONS

1. Energy Research Relations with Prospective Partners

- **Expanding Collaboration with African Nations:** India's highest priority under ISA should be collaborating on solar energy research with African countries. Much of Africa's solar potential remains untapped, and joint research programs can overcome continent-specific grid integration challenges and develop localised solar storage solutions. Shared research centres, funded by ISA member contributions, could accelerate innovation while fostering energy diplomacy.
- **Strengthening Ties with the European Union (EU):** The EU's Green Deal and India's renewable energy goals are closely aligned, providing a basis for cooperation in advanced PV technologies such as tandem solar cells and perovskite materials. Establishing innovation clusters between India and the EU would attract private investment and bridge technological gaps to benefit both partners.

2. Technology Transfer

- **Leveraging Multilateral Platforms for Transfer Agreements:** India should use platforms like the ISA to negotiate technology transfer agreements with technologically advanced countries. These agreements should focus on acquiring innovations in CSP technologies and high-efficiency solar PV modules.
- **Promoting Cooperation between PPPs and Indian Firms:** These agreements must ensure equitable terms, balancing intellectual property rights with developmental needs. The government can foster PPPs between Indian firms and global energy giants to enable technology localisation. Partnerships to manufacture bifacial solar panels domestically can enhance efficiency while lowering import dependency.

Establishing innovation clusters between India and the EU would attract private investment and bridge technological gaps to benefit both partners.

3. Cost-effective Manufacturing Capacity Among Energy Entrepreneurs

- **Scaling Domestic Production through Incentives:** The government should expand the existing PLI scheme by targeting small- and medium-scale enterprises (SMEs) in the solar manufacturing industry. Customised subsidies, tax benefits, and soft loans can motivate entrepreneurs to venture into solar component manufacturing, increasing domestic production.
- **Creating Regional Solar Manufacturing Hubs:** Establishing regional manufacturing hubs in economically underdeveloped states could balance industrial growth and reduce logistics costs. These hubs could also manufacture solar cells, inverters, and storage batteries for an end-to-end production ecosystem.
- **Promoting Innovation Through Start-ups:** India should encourage solar start-ups by setting up innovation parks with incubation support, funding opportunities, and mentorship programs. The main emphasis should be developing low-cost, efficient technologies tailored to rural and urban energy needs.

Only strategic international cooperation, innovative technology transfers, and strong manufacturing policies can harness India's solar energy potential. A balanced approach toward research, technology sharing, and support for entrepreneurship will also position India as a world leader in the solar energy sector, ensuring sustainable energy access within its borders.

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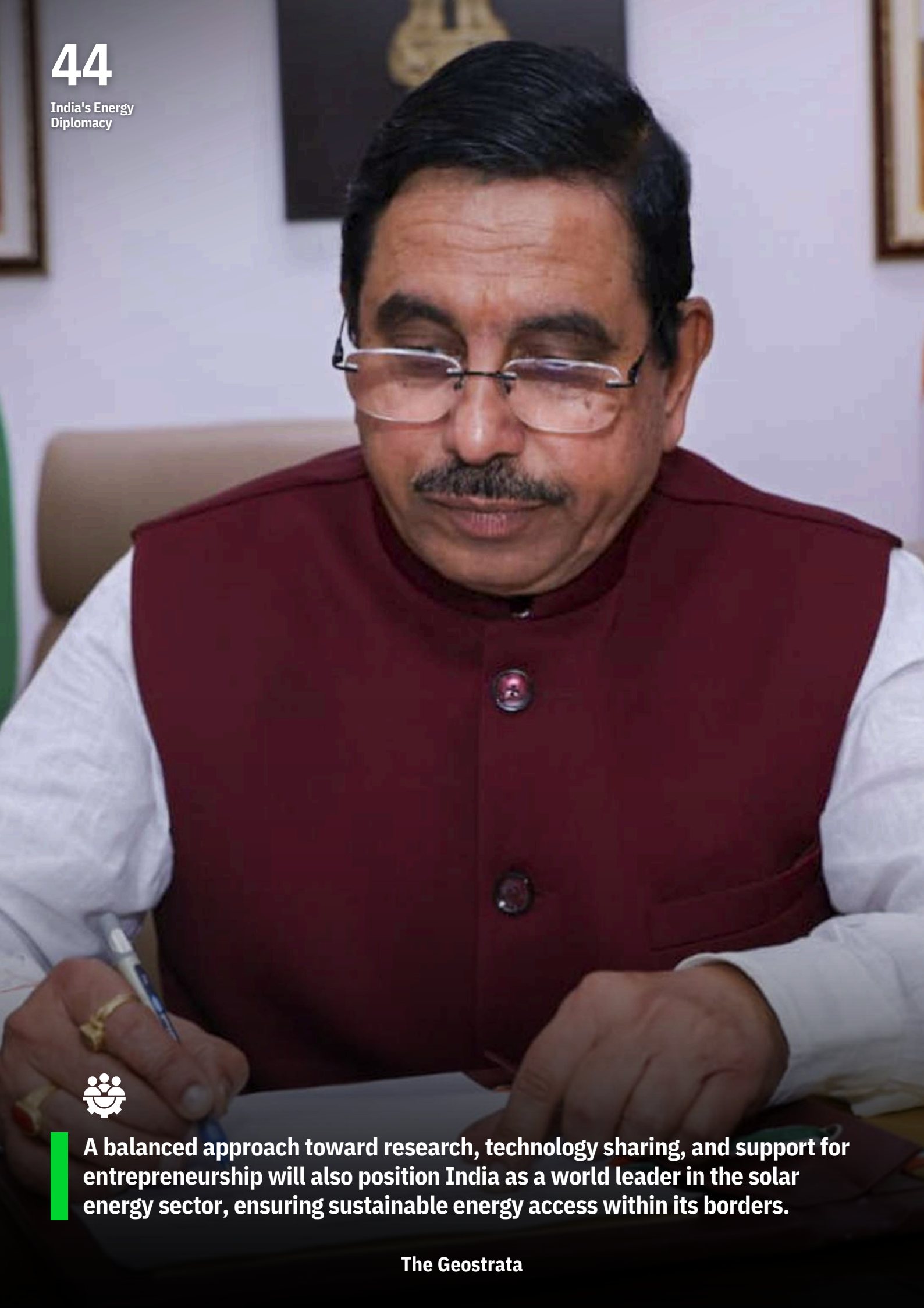
CONCLUSION

Achieving these visions will require infrastructure, targeted policy reforms, new investments, technical capacity building, and deepening international cooperation.

India’s energy diplomacy is emblematic of its commitment to addressing the twin challenges of energy security and climate change. By leveraging its geopolitical position, forging strategic international alliances, and adopting innovative technologies, India has emerged as a proactive player in the global transition to renewable energy. India's energy diplomacy includes exporting technical expertise, forming commercial partnerships with neighbouring nations, and shaping global discourse on sustainability.

This comprehensive report delineates part of a country's energy diplomacy on achieving energy security. It offers recommendations for the enhanced utilisation of renewable energy resources like biofuels, wind, geothermal and solar energy. On the geopolitical front, India’s leadership in platforms such as the International Solar Alliance and the Global Biofuels Alliance highlights its leadership role and commitment towards global climate goals.

However, achieving these visions will require infrastructure, targeted policy reforms, new investments, technical capacity building, and deepening international cooperation. Equally important will be a strategic approach towards climate financing, bridging technological gaps, and empowering local industries to align with global best practices. As India continues on its path to becoming a renewable energy powerhouse, its strategies are an example of balancing energy security with sustainability in front of the world, making it an emerging global player.



A balanced approach toward research, technology sharing, and support for entrepreneurship will also position India as a world leader in the solar energy sector, ensuring sustainable energy access within its borders.

Report Team

At Strata

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