Council for International Economic Understanding

bharat CLIMATE FORUM

Dalberg

Forum Report | Jan 2025

Bharat Climate Forum 2025

Scaling Cleantech Manufacturing for a Net-Zero, Atmanirbhar and Viksit Bharat

10 January 2025, ITC Maurya, New Delhi

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Foreword

As Chairperson of the Bharat Climate Forum Governing Team, it is a privilege to reflect on this transformative gathering of thought leaders, policymakers, and industry pioneers. The Forum's mission to align India's climate goals with its vision for Atmanirbharta and global leadership underscores the importance of cohesive action and innovative strategies in addressing the pressing challenges of climate change.

India stands at a pivotal juncture where global uncertainties and shifting geopolitical dynamics necessitate bold, unified responses. The journey toward sustainability is not merely an environmental imperative but a cornerstone of our economic resilience and global standing. With a legacy rooted in international climate negotiations, I am reminded of the critical evolution of climate commitments - from the Kyoto Protocol to the Paris Agreement, and most recently, COP29 in Baku. These milestones highlight both the progress we've made and the significant gaps that remain, particularly in financing and governance.

To achieve our ambitious targets of a 500 GW non-fossil energy installed capacity by 2030 and net-zero emissions by 2070, India must address its fragmented institutional framework and financial constraints. A unified approach—through initiatives such as a National Environment Council chaired by the Prime Minister—can harmonize efforts across central and state governments, private stakeholders, and scientific communities. At the same time, innovative financial mechanisms, blending concessional and commercial capital, are critical to unlocking the estimated USD 3 Tn required annually to drive climate action globally.

The Bharat Climate Forum serves as a catalyst for these conversations, emphasizing the need to scale green hydrogen production, extend the PLI scheme to energy-intensive sectors, and prioritize decarbonization across industries. By fostering industry-government collaboration and aligning policies with global best practices, India can emerge as a global leader in clean technology and climate resilience.

I am confident that the Bharat Cleantech Manufacturing Platform, launched at the Forum, will drive progress towards indigenization of our cleantech manufacturing sectors. The Platform will unite key players across sectors to tackle policy, investment, and technology challenges, positioning the country as a global leader in cleantech manufacturing.

As we navigate the complexities of climate action, let us reaffirm our commitment to sustainability as a unifying principle for growth and progress. This Forum has laid the groundwork for transformative policies and partnerships that will shape India's trajectory toward a greener, more resilient future.

I extend my heartfelt gratitude to the organizers and participants for their contributions to this critical dialogue. Together, we can build a sustainable, Atmanirbhar Bharat that leads the global fight against climate change.

N.K. Singh
Chairperson, Bharat Climate Forum Governing Team
Chairman, 15th Finance Commission

Bharat Climate Forum 2025

Foreword

It is an honour to reflect on the proceedings for the Bharat Climate Forum, a platform designed to drive meaningful dialogue and decisive action toward India's renewable energy and cleantech manufacturing ambitions. As the Co-Chairperson of the Bharat Climate Forum, I have had the privilege of contributing to this journey, which aligns deeply with the vision of positioning India as a global leader in clean energy and sustainable development.

India has an immense opportunity to reduce its dependency on imported energy, foster Atmanirbharta through robust domestic manufacturing, and establish itself as a pivotal player in the global cleantech landscape. With the nation aiming to achieve 500 GW of non-fossil energy installed capacity by 2030, we are at the cusp of a transformative journey. This transition is not just about addressing climate goals—it is equally about securing energy independence and strengthening India's role in global energy security.

Key to this ambition is the development of a holistic green industrial policy that supports the entire cleantech value chain, from manufacturing to infrastructure. Initiatives like the Production-Linked Incentive (PLI) scheme and import restrictions on solar modules have catalysed the growth of domestic industries, offering a compelling example of India's proactive and strategic policymaking. However, the challenges posed by global supply chain dependencies also demand targeted efforts to scale production, attract investments, and foster collaboration between industry and government.

The Bharat Climate Forum serves as a place to deliberate on such critical challenges and opportunities, building consensus among stakeholders, and lay the groundwork for actionable roadmaps that will be taken forward by the newly launched Bharat Cleantech Manufacturing Platform.

The driving thought behind this Platform is to accelerate progress in cleantech manufacturing and renewable energy adoption, and will include sector-specific and cross sector convenings to foster collaboration, share knowledge, and drive policy recommendations, addressing the entire cleantech manufacturing value chain.

I am confident that the insights and strategies discussed during the Forum, and in further deliberations of the Platform, will guide us in positioning India as a strong alternative in the global cleantech supply chain while driving sustainable economic growth at home.

I extend my gratitude to all those who have participated in and supported this endeavour. Together, let us channel the momentum generated at the Bharat Climate Forum to realize the vision of an inclusive and sustainable Atmanirbhar Bharat.

Sumant Sinha
Co-Chairperson, Bharat Climate Forum Governing Team
Chairman & CEO, ReNew

Executive Summary

Bharat Climate Forum

India aims for ambitious decarbonization goals, targeting net-zero emissions by 2070, 50% of energy from non-fossil sources by 2030, and 30% EV sales penetration for new vehicles within the same timeframe. While India's investment in green technologies is currently lower than that of the EU, US, and China (1.5% of GDP vs. 3-5%), there is **potential for significant increases to develop a self-sustaining cleantech ecosystem and a robust manufacturing base.**

Since 2014, India's renewable energy capacity has increased eightfold, supported by favourable policies and a thriving cleantech startup ecosystem. However, **the country still relies heavily on imports for high-value components,** especially for one source of origin, which exposes it to supply chain risks. **Strengthening domestic manufacturing could reduce vulnerability to external shocks, create jobs, and establish India as a green technology export hub.** Key opportunities include leveraging cost advantages in solar PV production and building a green workforce. With many countries adopting the 'China Plus One' strategy, India must act quickly to capture this momentum by positioning itself within an 'India Plus Many' framework. This approach would see India both ramp up its own manufacturing capabilities and collaborate with other emerging economies to create a diversified, resilient supply chain network. This will help with technology transfer and cost reduction for emerging economies in the Global South. Nonetheless, fragmented supply chains require a coordinated approach to stimulate investment and drive technological advancements.

In this context, and with the aim of identifying what it would take to accelerate Atmanirbhar Bharat in cleantech manufacturing, the **Bharat Climate Forum 2025** was held on **10th January 2025** at the ITC Maurya Hotel, New Delhi.

The Forum brought together **over 300 participants**, including policymakers, industry leaders, funders, researchers, and global allies across sectors. The event was marked by inspiring **keynote speeches from 5 esteemed speakers**, including the Honourable Ministers Piyush Goyal and Ashwini Vaishnaw. The proceedings featured **5 fireside chats, 7 panel discussions**, and **9 technical roundtables**, providing a platform for over **70 speakers** to share insights and explore strategies for strengthening cleantech manufacturing in India, **culminating in the launch of the Bharat Cleantech Manufacturing Platform.**

At the Forum, **a landmark Memorandum of Understanding was also signed between Dalberg, CIEU, and ISA in the presence of Honourable Union Minister Shri Piyush Goyal.** This agreement aims to foster cooperation to build and exchange knowledge, promote South-South collaboration for cleantech manufacturing, and support the vision of Prime Minister Shri Narendra Modi to position India as a global leader and a driving force for emerging economies. This milestone marks a proud moment for the participating organizations, symbolizing a shared commitment to furthering the objectives of the Bharat Cleantech Manufacturing Platform.

Bharat Cleantech Manufacturing Platform (BCMP)

To realise India's cleantech manufacturing potential, the **Bharat Cleantech Manufacturing Platform**, hosted by **Dalberg Advisors** and **Council for International Economic Understanding (CIEU)**, was launched at the Valedictory session of the Forum by **Shri Piyush Goyal, Honourable Union Minister of Commerce.**

The platform aims to unify key stakeholders across policy, industry, finance, and research sectors and position India as a global leader in cleantech manufacturing, fostering self-reliance as the cornerstone of its journey towards a Net-Zero and Viksit Bharat. The platform will focus on six key sectors - **Solar Energy, Wind Energy, Battery Energy Storage Systems (BESS), E-mobility, Green Hydrogen and Bioenergy.** The Platform's agenda includes sector-specific and cross-sector convenings to foster collaboration, share knowledge, and drive policy recommendations, addressing indigenization across the entire cleantech manufacturing value chain.

Initial activities under the Platform include creating a **comprehensive strategy and action plan** supported by conducting **sector specific assessments** to identify gaps and challenges facing each of the selected sectors; **identifying key pillars** such as R&D, Infrastructure, Financing, etc. which could have the highest impact for accelerating indigenization for each sector; **conducting pillar-level convenings** with key stakeholders to discuss challenges and potential unlocks at sector level for each pillar; and **identifying potential partnerships** at the local and global level to accelerate indigenization through areas including technology sharing, investments and market access.

The **Platform proposal has benefited from feedback from senior policymakers, public and private financiers, and industry players.** Several leading industry associations and research institutions have joined hands with the Forum and Platform as knowledge partners, bringing in-depth sector specific expertise to the Platform.

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Bharat Climate Forum 2025




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Bharat Climate Forum 2025

Context and Rationale

India has ambitious targets to achieve net-zero emissions by 2070, meet 50% of its energy needs from non-fossil sources by 2030, and EV30@30 objectives (30% EV sales penetration for new vehicles by 2030). The country's total installed energy capacity now stands at 442 GW, with renewables comprising about 33% and hydropower 11% of the total. Given the rapid pace of renewable energy (RE) installations, India is optimistic about achieving its 2030 targets ahead of schedule.

While these targets highlight India's commitment to clean energy, substantial challenges remain in reducing dependence on imported components. Globally, key economies like the EU, the US, and China have seen substantial capital flows into green investments, with the EU investing around 5% of GDP, the US at 3%, and China at 4% over the past few years, compared to India's current green investment levels, which stand at 1.5% of GDP. This disparity underscores India's significant potential to increase investment in its green transition, particularly to build a robust domestic manufacturing base that meets national needs and positions the country as a reliable partner for global supply chain diversification under the 'China Plus One' strategy. [1]

Progress on these targets in India has been complemented by clear policy incentives to promote domestic manufacturing across the cleantech value chain. For example, between 2010 and 2023, India's RE installed capacity increased eightfold, driven by supportive policies and decreasing costs of solar PV and wind technologies. Clear policy signals and financial innovations are driving investments in cleantech startups and expanding MSME participation. Growing venture capital investments in India's startup ecosystem have fuelled a surge in cleantech startups, with cleantech spending reaching USD 68 Bn in 2023—a 40% increase over the 2016-2020 average.[2],[3]

As more countries look to leverage the 'China Plus One' strategy, the competition to attract cleantech investments and build resilient supply chains is intensifying. Nations across Asia, Latin America, and Africa are positioning themselves as viable alternatives to China, seeking to capture a share of global manufacturing and investment flows. For India to stand out, it must not only increase its own capabilities but also adopt an 'India Plus Many' approach, collaborating with like-minded economies to create diversified, secure, and mutually beneficial supply chains. Strengthening India's role within this network will enhance its competitiveness, expand market access, and ensure long-term resilience in the cleantech sector.

Given India's ambitious clean energy goals across multiple sectors, domestic manufacturing must scale up to match this intent. Achieving these targets will require strong policies across the cleantech value chain to mobilize private sector investments and drive uptake among local manufacturers, where progress currently lags. Strengthening manufacturing capabilities will not only support India's clean energy transition but also build self-sufficiency and drive socioeconomic development.

With this focus, the Bharat Climate Forum was convened on 10th January 2025 at ITC Maurya to discuss the current status, opportunities and challenges for acceleration of indigenous cleantech manufacturing capacity and capabilities in India.

1. CEEW – CEF, "Milestone Markers: 18 Years of Renewable Energy Growth under National RE Policies and Regulations", 2024.
2 .IEA, "World Energy Investment 2024: India", accessed on November 2024.
3. Central Electricity Authority, "National Electricity Plan (NEP) (Vol-I Generation)", 2023.

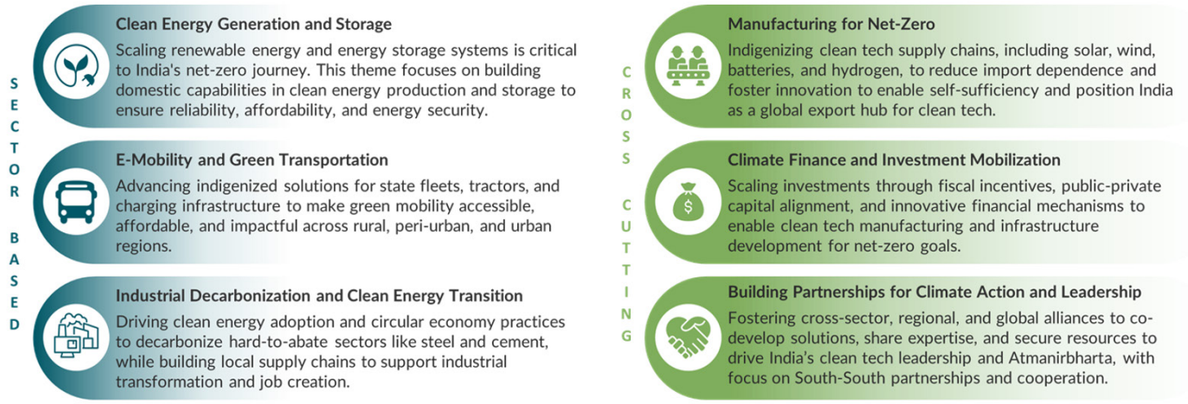
Bharat Climate Forum 2025

Aim and objective

The Bharat Climate Forum 2025 is aimed at positioning India as a manufacturing, fostering self-reliance (Atmanirbharta) as the cornerstone of its journey toward a Net-Zero and Viksit Bharat. Achieving net-zero by 2070 demands not only bold climate action but also a robust domestic manufacturing ecosystem to support renewable energy, green mobility, and sustainable industries. India's ambitious interim targets—reducing GDP emissions intensity by 45% from 2005 levels, achieving 50% of installed electricity capacity from non-fossil sources, and creating a 2.5–3 billion tonne CO_2 carbon sink by 2030—can only be met through self-reliance. Indigenizing production across critical cleantech value chains—from solar and wind to green hydrogen and battery storage—will strengthen economic resilience, create jobs, and ensure energy security to support lives and livelihoods while driving industrial growth. Atmanirbharta is not just a climate and an economic imperative. It is also a strategic necessity to reduce reliance on imports, secure supply chains, and harness India's potential as a global cleantech manufacturing hub. The Bharat Climate Forum 2025 sought to catalyse these efforts by bringing together policymakers, industry leaders, funders, and global allies to drive investments, foster innovation, and build partnerships that align India's net-zero ambitions with a vision for sustainable development, inclusive growth, and self-reliance.

The forum focused on six foundational themes that are critical to driving India's net-zero ambitions through self-reliance and cleantech leadership:

Figure 2: Foundational themes for Bharat Climate Forum



The subsequent sections of this report focus on the key insights from the sessions of the forum including the 9 roundtable discussions which were held in parallel. The conclusion of the report summarises the next steps and plan ahead for the Bharat Cleantech Manufacturing Platform.

Forum Agenda

0915 –1000 Hrs
REGISTRATION

1000 – 1030 Hrs
INAUGURATION AND WELCOME ADDRESS BY ASHWANI MAHAJAN, SUMANT SINHA, MEENAKSHI LEKHI AND N K SINGH

1030 –1050 Hrs
INAUGURAL ADDRESS BY HON'BLE MINISTER, MEITY AND RAILWAYS, ASHWINI VAISHNAW

1050 –1120 Hrs
INAUGURAL FIRESIDE CHAT: BHARAT'S POTENTIAL AS CLEANTECH MANUFACTURING HUB
Ram Madhav, *President, India Foundation*
Bhupinder Singh Bhalla, *Former Secretary, MNRE*

MODERATOR:
Jagjeet Sareen, *Partner, Global Climate Lead, Dalberg Advisors*

1120 – 1150 Hrs
VIKSIT BHARAT: A VISION FOR NET ZERO THROUGH ATMANIRBHARTA

PANELISTS:
Ashwini Kumar Tewari, *Managing Director (Corporate Banking and Subsidiaries) of State Bank of India*
N S Vishwanathan, *Former Deputy Governor, RBI; Non-Executive Chairperson, Axis Bank*
Pratik Agarwal, *Chairman, Serentica Renewable; MD, Sterlite Power*
Sumant Sinha, *Founder, Chairman and CEO of ReNew*

MODERATOR: Anita George, *CEO, ProsperETE*

1150–1220 Hrs
FIRESIDE CHAT: ROLE OF GOVERNMENT IN ACCELERATING CLEANTECH MANUFACTURING IN INDIA

Suresh Prabhu, *Former G20 Sherpa and Cabinet Minister of India (Commerce, Civil Aviation and others)*
Shashank Mani, *Member of Parliament, Lok Sabha*
Ashwin Johar *Member, IRBC, NITI Aayog; Erik Solheim, Former Minister of Climate and the Environment of Norway*
Moderator:
Shirish Sinha, *Executive Director of Programmes, Clean Air Fund*

1220 –1300 Hrs
PANEL DISCUSSION
DELIVERING ON THE TRANSITION: CAN BHARAT BECOME COST-COMPETITIVE BY INDIGENIZING CLEAN TECH MANUFACTURING?

KEYNOTE ADDRESS:

Amitabh Kant, *India's G20 Sherpa*

Bharat Climate Forum 2025

PANELISTS:
Girish Tanti, *Co-founder, Suzlon India*
Gyanesh Chaudhary, *CMD, Vikram Solar*
Vineet Mittal, *Chairman, Avaada Group*
Bhupinder Singh Bhalla, *Former Secretary, MNRE*
Jon Creyts, *CEO, Rocky Mountain Institute*
Nagesh Kumar, *Director and Chief Executive, Institute for Studies in Industrial Development (ISID)*

MODERATOR: Ila Patnaik, *Chief Economist, Aditya Birla Group*

1300 –1400 Hrs
LUNCH BREAK

1400 –1430 Hrs
PANEL DISCUSSION
Strengthening Bharat's Clean Tech and Manufacturing Ecosystem: Connecting Ideas, Innovation, and Industry

PANELLISTS:

Anjali Bansal, *Founding Partner, Avaana Capital*
Amit Singh, *Chief Executive Officer, Adani Green Energy Ltd.*
Sangeeta Kaushik *Executive Director, NTPC*
Prof. Ambuj Sagar, *Vipula and Mahesh Chaturvedi Professor of Policy Studies, Indian Institute of Technology Delhi*
Hemang Jani, *Senior Advisor to the Indian Executive Director at the World Bank Group, and Board Member of Atal Innovation Mission, India*
Moderator: Dhruba Purkayastha, *Director for Growth and Institutional Advancement with Council on Energy, Environment and Water (CEEW)*

1430 –1500 Hrs
PANEL DISCUSSION
PATHWAYS FOR INDIA'S TRANSITION TO GREEN MOBILITY: ROLE OF HYBRID VS. EVS AND OTHER TECHNOLOGIES

PANELLISTS:

Anand Kulkarni, *Chief Product Officer, Passenger Electric Vehicle, Tata Motors Limited*
Abanti Sankaranarayanan, *Chief Group Public Affairs Officer and a Member of the Group Executive Board of Mahindra and Mahindra Ltd.*
Anirudh Arun, *Co-Founder and CEO, Blu-Smart*

MODERATOR: Mahua Acharya, *Founder – INTENT, Ex-MD and Ex-CEO, CESL*

1520 – 1550 Hrs
PANEL DISCUSSION
FROM WORKERS TO ENTREPRENEURS: BUILDING BHARAT'S WORKFORCE FOR CLEAN TECH MANUFACTURING

PANELISTS:

Adil Zainulbhai, *Chairman, Capacity Building Commission, Government of India*
Arpit Sharma, *CEO, Skill Council for Green Jobs*
S Sunder Manoharan, *Vice Chancellor, Pandit Deendayal Energy University, Gandhinagar, Gujarat*
Amit Singh, *Chief Executive Officer, Adani Green Energy Ltd.*
Manish Kumar, *Visiting Professor for Economics, Indian School of Business; Former MD and CEO, National Skill Development Corporation (NSDC)*

MODERATOR: Aakash Sethi, *CEO, QUEST Alliance*

1550 – 1620 Hrs
High-level fireside chat on: BHARAT Manufacturing Model: Win-win for World

Ashok Kantha, *Former Indian Ambassador to China*

Shyam Saran, *Former Foreign Secretary, Govt of India*
Shaurya Doval, *Director, India Foundation and MD, Torch Investment Management*

Moderator:
Gaurav Gupta, *Global Managing Partner, Dalberg Advisors*

1620 – 1700 Hrs
PANEL DISCUSSION
GLOBAL PARTNERSHIPS FOR GREEN AMBITIONS: TECHNOLOGY, TRADE, AND RESOURCES

KEYNOTE ADDRESS:
Meenakshi Lekhi, *Former Minister of State for External Affairs, and Culture*

PANELISTS
Taranjit Sandhu, *Former Indian Ambassador to the USA*
Lekhan Thakkar, *Joint Secretary, National Security Council, India*
Lord Adair Turner, *Chair, Energy Transitions Commission*

MODERATOR: Sachin Chaturvedi, *DG, RIS*

1700 – 1730 Hrs
FIRESIDE CHAT: HOW TO MAKE RURAL INDIA CLIMATE READY?

Prof. Ramesh Chand, *Member, NITI Aayog*
Ashwani Mahajan, *National Co-Convener, Swadeshi Jagaran Manch*
Vikram Shroff, *Vice-Chairman and Co-CEO, UPL Group*

Moderator:
Komal Shah Bhukhanwala, *Director, SML Group*

1730 – 1810 hrs
Financing an Atmanirbhar Bharat: Unlocking Capital for Clean Tech Manufacturing

KEYNOTE ADDRESS:
Jayant Sinha, *Former Minister of State, Finance*

PANELLISTS
NIVRUTI RAI, *CEO, Invest India (Special address)*
ANNIKA SEILER, *Lead – Clean Energy Supply Chains, ADB*
AUGUSTE TANO KOUAMÉ, *Country Director for India, World Bank*
RAJNISH KUMAR, *Former Chairperson, SBI*

MODERATOR: Shalabh Tandon, *Regional Head of Operations & Climate Change, IFC South Asia*

1810 –1850 Hrs
FIRESIDE CHAT: CHANGING GLOBAL GREEN ORDER: OPPORTUNITIES FOR INDIA

Sumant Sinha, *Founder, Chairman and CEO of ReNew*
Henrik Skovby, *Founder and Global Chairman, Dalberg Group*
Dr. Ajay Mathur, *Director General, ISA*
Manjeev Puri, *Former Ambassador of India to the EU, Nepal and the UN*

MODERATOR: Ovais Sarmad, *Vice Chair of the Greenhouse Gas Protocol Steering Committee, Former Deputy Executive Secretary, UNFCCC*

1850 –1935 Hrs
Valedictory session and welcome of Hon'ble Minster, Commerce, Piyush Goyal

1850 –1905 Hrs
Insights on BCF technical roundtables by knowledge partners and industry associations - Jagjeet Sareen, Partner, Global Climate Practice, Dalberg Advisors

1905 –1935 Hrs
Ministerial address and launch of Bharat Cleantech Manufacturing Platform, Hon'ble Minster, Commerce, Piyush Goyal

2000 – 2200 Hrs
NETWORKING DINNER

Technical Roundtables

Venue - A

1040 –1140 Hrs
TECHNICAL ROUNDTABLE
MOBILIZING INVESTMENTS AND FINANCING FOR CLEANTECH MANUFACTURING IN INDIA- WHAT IS THE ROLE OF DEVELOPMENT FINANCE

MODERATOR(S):
Sujatha UG, *Vice President - Global Partnerships & Net Zero, Invest India*
Amit Jain, *Senior Energy Specialist, World Bank,*

1200 –1300 Hrs
TECHNICAL ROUNDTABLE
LIGHTING THE WAY: SOLAR SOLUTIONS FOR A SELF-RELIANT BHARAT

MODERATOR(S):
A K Saxena, *Senior Director, TERI and will moderate the technical roundtable discussion.*

1430 –1530 Hrs
TECHNICAL ROUNDTABLE
THE HYDROGEN OPPORTUNITY: CAN INDIA LEAD THE GLOBAL SHIFT?

MODERATOR(S):
Deepak Yadav *Senior Program Lead, Council on Energy, Environment and Water (CEEW)*

1550 –1650 Hrs
TECHNICAL ROUNDTABLE
ELECTRIFYING BHARAT: THE ROLE OF BATTERY STORAGE IN ACHIEVING NET-ZERO

MODERATOR(S):
Jagabanta Ningthoujam, *Principal, RMI*

1730 –1830 Hrs
TECHNICAL ROUNDTABLE
ROLE OF NBFCS IN SUPPORTING CLEAN TECHNOLOGIES

MODERATOR(S):
Vivek Sen, *India Director, Climate Policy Initiative (CPI)*
Raman Aggarwal, *Director (& Former Chairman), Finance Industry Development Council*

Technical Roundtables

Venue - B

1200 –1300 Hrs
TECHNICAL ROUNDTABLE
CHARGING AHEAD: BHARAT'S JOURNEY TO GREEN MOBILITY SELF-RELIANCE

MODERATOR(S):
Mahua Acharya , *Founder, INTENT, Ex-MD and Ex-CEO of Convergence Energy Services Limited*
Akshima Ghate, *MD India, Rocky Mountain Institute*

1430 –1530 Hrs
TECHNICAL ROUNDTABLE
HARNESSING THE WIND: LOCAL SOLUTIONS ACROSS THE WIND ENERGY VALUE CHAIN
MODERATOR(S):
Sidharth Jain, *Founder and MD, MEC+*

1550 –1650 Hrs
TECHNICAL ROUNDTABLE
FUELLING THE FUTURE: LOCALIZING BIOENERGY SUPPLY CHAINS

MODERATOR(S):
Swapan Mehra , *CEO, Iora Ecological Solutions*
Dr. D.K.Khare , *Senior Advisor, Global Green Growth Institute*

1730 –1830 Hrs
TECHNICAL ROUNDTABLE
GLOBAL TRADE AND CLIMATE DYNAMICS: IMPACT AND ROLE OF GREEN TARIFFS, NEARSHORING, DOMESTIC REGIME AND OTHER TRADE SHIFTS ON CLEANTECH MANUFACTURING AND GREEN ENERGY

MODERATOR(S):
Dr. Pritam Banerjee, *Professor & Head, Centre for WTO Studies Indian Institute of Foreign Trade*

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Global Climate Co-Lead, Dalberg

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Inauguration and Welcome Address

The Bharat Climate Forum commenced with an impactful inaugural address delivered by esteemed CIEU Chairpersons and Board Members – Ashwani Mahajan, Sumant Sinha, N.K. Singh, and. Meenakshi Lekhi. Their visionary insights set the tone for the forum's focus on driving sustainable solutions and championing India's leadership in the global cleantech agenda

Ashwani Mahajan
Member Secretary National Co-convener, Swadeshi Jagaran Manch

Sumant Sinha
Co-Chairperson Founder, Chairman and CEO, ReNew

N K Singh
Chairperson Chairman, 15th Finance Commission of India

Meenakshi Lekhi
Convenor Former Minister of State for External Affairs and Culture

Welcome address by Dr. Ashwani Mahajan

Dr. Ashwani Mahajan is the Member Secretary of the Bharat Climate Forum Governing cum organizing team, the National Co-Convener of Swadeshi Jagaran Manch (SJM) and Chief Editor of the Journal of Contemporary Indian Polity and Economy since 2011. A former Associate Professor at PGDAV College, Delhi, he has also served as a Visiting Professor and research guide at Pacific University and Mewar University. An active researcher and WTO activist, he has represented the Swadeshi Jagran Foundation at ministerial conferences in Geneva, Bali, and Nairobi.

A prominent advocate of Atmanirbhar Bharat, he delivered a compelling welcome address emphasizing India's readiness to become self-reliant in climate technologies. Framing climate change as an undeniable reality threatening humanity, he underscored the urgency of transitioning away from fossil fuels towards sustainable, low-emission solutions such as EVs, solar, and green hydrogen. His speech reflected India's resolve to innovate and lead in clean technologies while addressing global inequities in technology transfer and dependency on foreign players.

The speech celebrated India's strides in clean technology sectors, particularly wind, solar, and EVs. It was noted that India has reduced its reliance on foreign nations, with significant progress in wind power (58-70% indigenization) and solar energy (moving from 100% to 80% dependency).[4] These achievements, while notable, also highlighted the work still required to achieve full self-sufficiency.

Dr. Mahajan emphasized the critical need for a robust and holistic cleantech manufacturing policy to achieve Atmanirbhar Bharat in cleantech technologies. Such a policy must address challenges like high interest rates, low investor confidence, and regulatory barriers. Tariff controls, quality standards, and incentives for local innovation were presented as necessary components to boost domestic production and ensure competitiveness. Acknowledging the different needs and objectives of different stakeholders, Dr. Mahajan advocated for focusing on solutions that would be incremental to the current efforts, accelerate technological advancements and prioritize humanity and the nation's best interests. He stressed that India must also pursue technology improvements such as hybrids or other transitional innovations while keeping its focus on long-term sustainability.

Dr. Ashwani Mahajan's address laid a roadmap for India's journey towards Atmanirbhar Bharat in cleantech. By building robust manufacturing policies and fostering innovation in key sectors like EVs and renewable energy, India is positioning itself as a leader in sustainable solutions. His vision emphasized collaboration, resilience, and a focus on humanity's collective welfare to ensure India not only achieves self-reliance but also contributes meaningfully to global emissions mitigation.

4.CEEW, Strengthen India's Clean supply chain, 2024

Welcome address by Mrs. Meenakshi Lekhi

Mrs. Meenakshi Lekhi is the Convenor for the Bharat Climate Forum Governing cum organizing team. An accomplished politician and lawyer, she served as Minister of State for External Affairs and Culture (2021–2024) and has been a Member of Parliament from New Delhi since 2014. She has focused on urban development, cultural diplomacy, and renewable energy, championing initiatives like the International Solar Alliance and the 'Green Highways Policy,' while strengthening India's global partnerships in clean energy and cultural exchange.

In her welcome address, Mrs. Meenakshi Lekhi emphasized the critical intersection of energy transition, sustainability and smart urban planning. Speaking at a time when cities like Delhi face mounting energy demands and environmental challenges, Mrs. Lekhi underscored India's leadership in sustainable energy practices while addressing global narratives around climate diplomacy. Her address highlighted India's achievements, challenges, and the need for reframing global discussions about its energy transitions.

Mrs. Lekhi highlighted India's minimal per capita carbon footprint relative to its massive population, showcasing it as a global model of sustainable growth. Despite contributing only 2.1 tons of carbon emissions per capita,[5] India has taken substantial steps towards transitioning to green energy without having significantly contributed to historical climate change. As a nation committed to self-sustained climate goals, India is on track to achieve its 2030 target of non-fossil energy constituting 50% of installed capacity, having crossed 46% of total capacity as on October 2024,[6] and ranks fourth[7] and fifth[8] globally in wind and solar energy installed capacity, respectively.

Mrs. Lekhi highlighted the broad benefits of transitioning to non-fossil fuels, emphasizing how such initiatives contribute to public health, sustainability, job creation, and supply chain resilience. India's push for renewable energy technologies, including solar manufacturing and off-grid connectivity represents a significant economic opportunity along with an environmental opportunity. These initiatives align with India's goal of becoming a global leader in sustainable energy while fostering greater economic returns and investments.

Mrs. Lekhi's address highlighted India's significant strides in sustainable energy, making it a global leader despite its low historical contribution to climate change. She stressed the need for leveraging energy transitions to drive economic resilience and job creation. Her call for pragmatic global energy policies reflected her belief in the need for fairness in international cooperation. Mrs. Lekhi's remarks served as a rallying cry for India to not only lead by example but also shape the global discourse on energy transitions and climate diplomacy.

5.Our World in Data, India CO2 Country Profile, 2023
6.PIB, India's Renewable Energy Capacity Hits New Milestone, 2024
7.Our World in Data, Installed Wind Energy Capacity, 2023
8.Our World in Data, Installed Solar Energy Capacity, 2023

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Inaugural Address by Honourable Minister Ashwini Vaishnaw

Shri Ashwini Vaishnaw, Honourable Minister of Railways, Information & Broadcasting, and Electronics & IT, delivered an inspiring keynote during the inaugural session. He has been instrumental in driving technological innovation and infrastructure development in India. He has expanded India's railway network with 772 new services, including Vande Bharat trains, and was named among TIME's 100 most influential people in AI for 2024, leading efforts in AI and semiconductor manufacturing.

Drawing from his extensive experience in policymaking and technology development, he discussed India's transformative journey toward Atmanirbhar Bharat and Make in India, focusing on fostering technological innovation, building robust collaborations, and leveraging frugal engineering for global competitiveness. Sharing anecdotes from projects such as the indigenous development of 4G/5G telecom stacks, the Vande Bharat trains, and India's semiconductor program, he highlighted the critical elements driving India's path to self-reliance and its emerging role as a global manufacturing leader.

Shri Vaishnaw underscored the importance of a mindset of perseverance, discipline, and problem-solving as the foundation of innovation. He illustrated this with the development of India's 4G/5G telecom stack, a project initiated under the Prime Minister's vision for domestic technology. He shared how despite formidable competition from global giants like Huawei and Ericsson, India achieved success by virtualizing its radio access network and adopting an interoperable architecture. Similarly, the indigenous design and deployment of Vande Bharat trains demonstrated how a determined mindset enabled the engineering of high-speed, power-intensive trains, despite immense technical challenges. His message was clear: embracing challenges with a growth mindset can propel India into global leadership in clean and advanced technologies.

The minister highlighted that achieving ambitious projects like semiconductor manufacturing and telecom infrastructure necessitates partnerships across sectors and geographies. The semiconductor mission, a critical component of India's vision, involved coordinating with global value chains, state governments, and power companies to establish precision-dependent manufacturing capabilities. He emphasized how such collaborations allowed India to create a 20-year roadmap for semiconductor self-sufficiency, aligning efforts across international stakeholders, domestic industries, and policy frameworks. Effective partnerships, according to Shri Vaishnaw, are indispensable for building a resilient and self-reliant technology ecosystem.

India's ability to innovate with limited resources was highlighted as a key differentiator in global markets. The minister explained how frugal designs – while not always aesthetically superior – could deliver cutting-edge technological solutions at competitive prices. Citing examples of wind turbine blades and other innovations, he emphasized how the combination of frugality and excellence in technology can allow India to carve a niche in the global market. This approach, he emphasized, would enable India to meet its domestic needs while also competing internationally.

In conclusion, Shri Ashwini Vaishnaw talked about how India's path to self-reliance hinges on fostering a mindset of resilience and innovation, building a collaborative ecosystem across domestic and global stakeholders, and leveraging its unique strength in frugal engineering to create world-class, cost-effective technologies. Long-term planning, exemplified by the 20-year roadmap for the semiconductor mission, ensures sustainable progress, positioning India as a global leader in advanced manufacturing and clean technologies. Minister Vaishnaw's keynote underscored the importance of aligning innovation with strategic collaboration to achieve Atmanirbhar Bharat and establish India as a competitive force on the global stage.

INAUGURAL FIRESIDE CHAT

BHARAT'S POTENTIAL AS CLEANTECH MANUFACTURING HUB

The inaugural fireside chat on **Bharat's potential as cleantech manufacturing hub** was held between Ram Madhav, President, India Foundation; and **Bhupinder Singh Bhalla,** Former Secretary, MNRE; and was moderated by **Jagjeet Sareen,** Partner and Global Climate Lead, Dalberg Advisors.

The chat focused on India's potential to transition from a major importer to a global leader in cleantech manufacturing, addressing challenges in workforce readiness, R&D investment, infrastructure, and policy consistency. It emphasized the need for systemic reforms, strategic investments, and collaboration to achieve Atmanirbharta and cost competitiveness in the global market.

Context for fireside chat

The fireside chat on Bharat's potential as a cleantech manufacturing hub sought to address a profound and pressing question: is India ready for Atmanirbharta while striving to become a developed nation, or Viksit Bharat? With conflicting priorities such as green jobs, economic growth, managing environmental challenges, and eradicating poverty, the discussion highlighted the enormity of India's task. The session centred around evaluating India's preparedness to transition from being a significant importer of clean technology to becoming a global manufacturing leader in this domain. Key themes included the gaps in workforce readiness, the progress and untapped opportunities of the past two decades, and the urgency to align India's cleantech aspirations with its strategic economic goals. The speakers discussed India's standing across critical dimensions such as renewable energy capacity building, policy implementation through programs like the PLI scheme, and the nation's response to the global dominance of China in cleantech manufacturing. The overarching focus was on whether a cohesive national mission could propel India toward self-reliance and cost competitiveness while addressing the twin challenges of climate change and industrialization.

Insights from the fireside chat

India's cleantech ambitions hinge on addressing systemic gaps in education, R&D, manufacturing, and infrastructure. The discussion highlighted that while India aspires to achieve self-reliance, its education system needs to transform in-line to create a workforce skilled in renewable energy technologies. One of the key gaps discussed was the limited practical exposure during graduation years increasing the need for on-the-job training and increases costs and timelines for such knowledge building. The need for market-driven educational frameworks was emphasized, suggesting that private companies should play a larger role in developing industry-specific educational infrastructure to bridge these gaps.

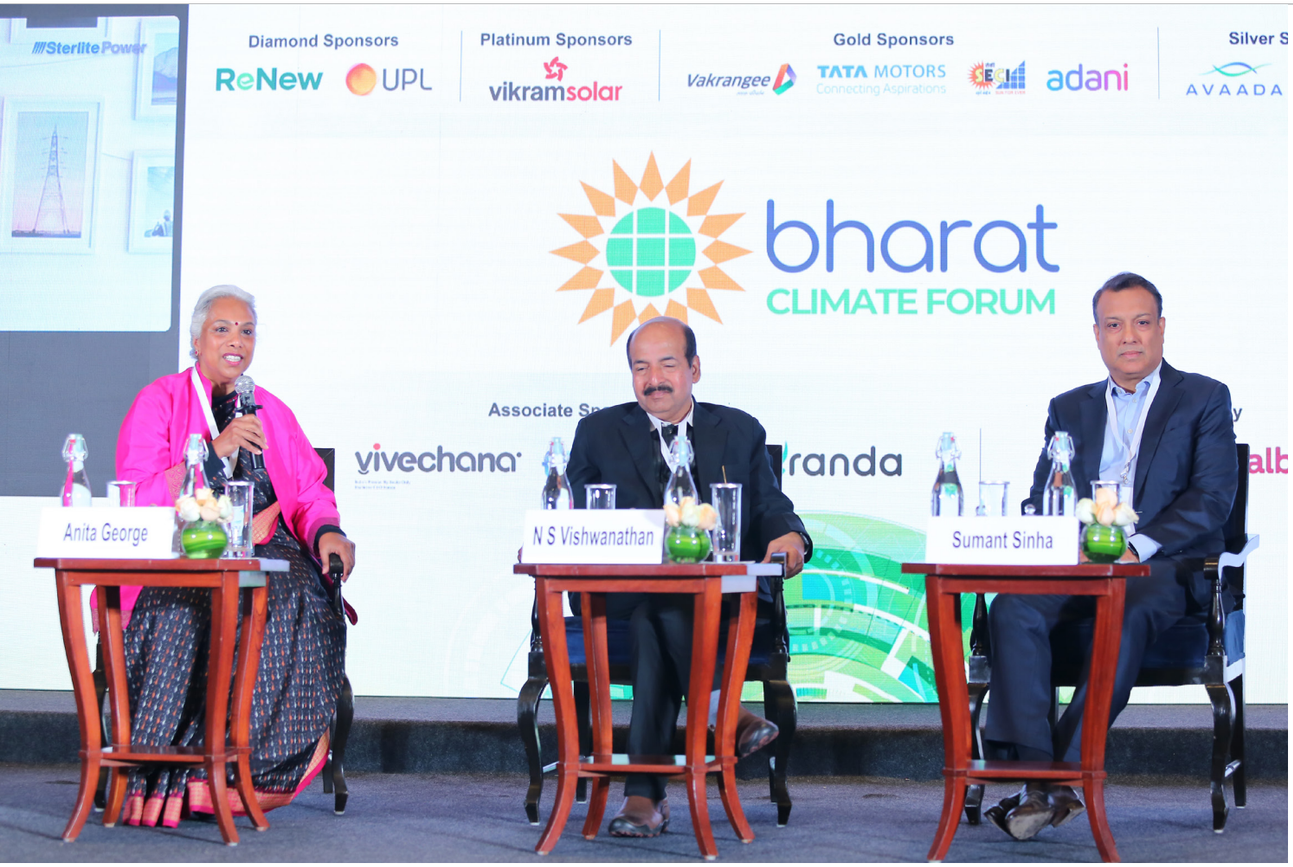
India's relative underinvestment in R&D is a critical barrier to achieving Atmanirbharta in cleantech manufacturing. Speakers underscored that India spends just 0.6% of its GDP on renewable energy R&D, far behind countries like the US, China, Japan, South Korea and EU, which allocate 2-5%.[9] This disparity stifles innovation and perpetuates dependency on imports, particularly from China. The speakers advocated for a more robust R&D ecosystem that prioritizes cutting-edge technologies, such as carbon capture and battery recycling, and stressed the importance of industry-driven research initiatives to complement government efforts.

Scaling domestic manufacturing capacity and ensuring product readiness are pivotal for achieving India's renewable energy goals. The discussion revealed that while India has made significant progress in solar module manufacturing, challenges persist, and opportunities exist in the production of upstream components like cells, wafers, and polysilicon. Additionally, the readiness of grids and EV charging networks to handle expanded renewable energy integration remains a concern. Speakers recommended accelerating infrastructure development, ensuring policy consistency, and leveraging schemes like the PLI to scale production while fostering an environment conducive to investments.

Speakers also underscored the importance of the geopolitical opportunity for India presented by global trade shifts to position itself as a cleantech leader. With the US and EU starting to impose tariffs on Chinese imports, India could emerge as a reliable alternative in global supply chains if it could achieve cost competitiveness in cleantech manufacturing. However, achieving cost competitiveness requires systemic reforms, including reducing logistics costs, simplifying regulations, and creating predictable policies.

The speakers agreed that India's journey toward Atmanirbharta in cleantech must be anchored in systemic reforms, strategic investments, and enhanced collaboration between stakeholders. By leveraging its market size, intellectual capital, and favourable geopolitical climate, India has the potential to become a global leader in cleantech manufacturing. However, achieving this vision will require not just ambition but also meticulous planning and execution across sectors.

9.Department of Science and Technology (DST), Government of India, R&D Statistics at a Glance 2022-23



VIKSIT BHARAT: A VISION FOR NET ZERO THROUGH ATMANIRBHARTA

The panel discussion on **'Viksit Bharat: A Vision for Net Zero through Atmanirbharta'** was held between **Ashwini Kumar Tewari,** Managing Director (Corporate Banking and Subsidiaries) of State Bank of India; **N S Vishwanathan,** Former Deputy Governor, RBI; Non-Executive Chairperson, Axis Bank; **Pratik Agarwal,** Chairman, Serentica Renewable; MD, Sterlite Power; and **Sumant Sinha,** Founder, Chairman and CEO of ReNew; and was moderated by **Anita George,** CEO, ProsperETE.

Context and rationale

India has set ambitious targets to achieve net-zero emissions by 2070, with interim milestones such as 500 GW[10] of non-fossil energy installed capacity and EV30@30 objectives (30% EV sales penetration for new vehicles by 2030[11]). These goals highlight the country's commitment to a sustainable and energy-secure future.

In recent years, India has made significant progress in renewable energy and electric mobility, supported by favourable government policies,

10. Ministry of power, 500 GW Non-fossil Fuel Target | Government of India
11.The Hindu, Aim to have 30% of 2030 car sales as EVs, 2021
12. IEA, India – World Energy Investment 2024 – Analysis, 2024
13.NITI, India's Power Sector | Capacity & Generation Mix, 2024

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growing private sector participation, and a thriving startup ecosystem. PLIs, FAME and other subsidies and incentives from the government for renewable energy and EV have enabled an increase in investments. Annual investments in cleantech reached a record USD 68 Bn in 2023 (a 40% increase over the 2016-2020 average),[12] with nearly half allocated to renewable energy.

Figure 1: India's total installed capacity for energy (GW)

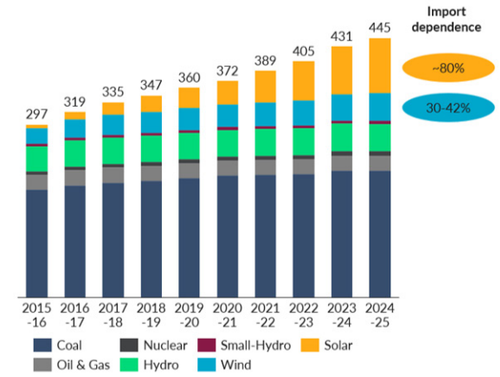
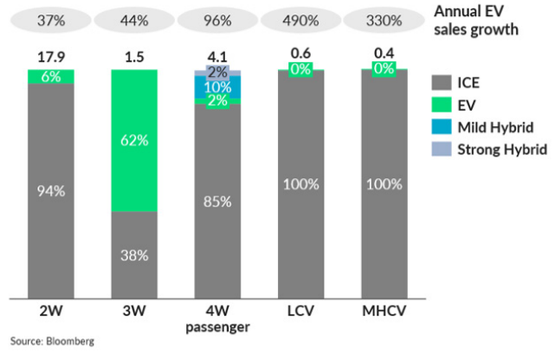


Figure 2: New vehicle sales by category and drivetrain in India, 2023 (Mn vehicles)



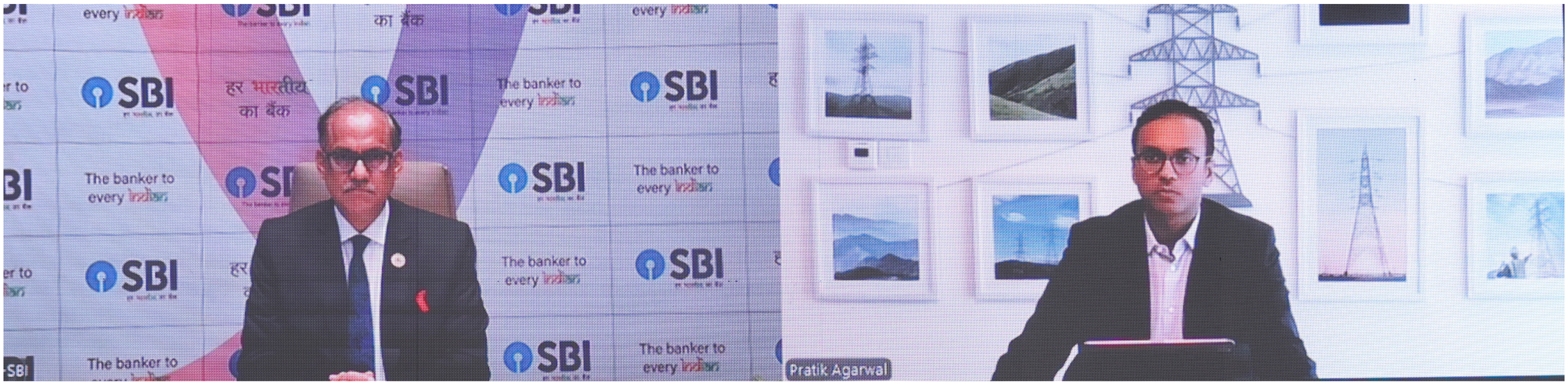
Source: Bloomberg

India's renewable energy capacity has grown at a CAGR of 10% since 2015, led by solar at 34% CAGR[13] (Figure 3). However, ~80% of the current installed capacity is dependent on imports for solar and up to 42% for wind indicating insufficient domestic capacity to meet the growing demand and a potentially higher import dependence. The PLI scheme for High Efficiency Solar PV modules,[14] announced in 2021 is enabling indigenization of the solar value chain through a USD 3 Bn incentive for 48 GW domestic solar PV module is enabling this shift. As demand for energy storage would also increase along with the growing renewable energy demand, the current ~90% import dependence would also need to be addressed to drive self-reliance and reduce price fluctuations due to global trade dynamics.

EV sales grew by 26.5% in 2024 compared to the previous year to nearly 2 million units[15] , raising share of sale from 6.39% in 2023 to 7.46%[16] (Figure 4). While progress is evident, achieving the EV30@30 target of 30% sales penetration for new vehicles by 2030 remains a significant challenge across domestic capacity and TCO (total cost of ownership) for electric vehicles. While supportive policies such as FAME have supported indigenization of EV value chains and helped reduce the TCO for 2 and 3-wheelers, TCO challenges remain on passenger 4-wheelers. These could be adversely impacted with reduction in government incentives for electric vehicles. With ~90% import dependence for battery cells and packs and 60-70% import reliance for motor and drivetrain components, there is still a considerable path for achieving indigenization for EV value chains. There are green shoots and success stories on indigenization of EV value chains with OEMs such as Ola Electric and Tata Motors achieving more than 50%[17] and 70%[18] indigenization respectively, but there is still a long way to go for India to achieve self-reliance across the entire EV value chain including battery cell and pack design.

Beyond these advances in renewable energy sources, India has also made remarkable progress in biofuels, including bioethanol blending. Bio-ethanol blending rose from 1.5% in 2014 to 15% in 2024,[19] saving USD 13 Bn in foreign exchange and reducing emissions by 55 million tonnes CO2e. This was driven by a doubling of production capacity to 16 Bn liters by September 2024 indicating a strong trend of self-reliance for bio-ethanol and almost achieving the required capacity to meet the E20 target. Policies such as modified Pradhan Mantri JI-VAN Yojana support the establishment of Second Generation (2G) bioethanol projects and so do the recent approvals of multiple 2G bioethanol plants. However, India has not been able to achieve similar success across other bio-fuels and supply chains for CBG, an essential low-carbon fuel for hard-to-abate sectors and transport, is grappling with challenges of

14.MNRE, PLI details
15.IBEF, EV sales in India up 27% in 2024, 2024
16.Business Standard, EV sales in India up 27% in 2024, 2024
17.Ola Electric, Press release
18.Business Standard, Tata Motors to increase localization of electric vehicles to 85%, 2023
19.PIB, India's Ethanol Push: A Path to Energy Security, 2024



high production costs and limited infrastructure and demand drivers.

The high-import reliance and indigenous capacity gaps also reflect in India's investment in cleantech manufacturing. India currently invests around 1.5% of its GDP in cleantech, well below the global average of 3–5%. To meet its renewable energy targets, India needs an annual requirement of USD 120–140 Bn across all sectors, rising to a cumulative USD 7.2–12.1 Tn by 2050.[20] While investments have grown at 13% CAGR since 2004, significant gaps remain[21] and a strong focus on indigenization across cleantech supply chains is required to accelerate self-reliance across sectors.

In addition, the government's focus on emerging sectors, such as green hydrogen through the National Green Hydrogen Mission, is promising but demands an additional USD 96 Bn investment by 2030.[22] Similarly, achieving ~209 GWh of battery storage capacity requires USD 68 Bn[23] in investments over six years, far exceeding current progress (219 MWh till March 2024). There is focus to also drive indigenization of Battery Energy Storage Systems, where we have high-import dependence currently, through enablers like the ACC PLI scheme and to recover end-of-life materials through EPR policies on e-waste.

To meet this growing demand, driving self-reliance through indigenization of cleantech manufacturing across sectors at competitive costs is essential. India's reliance on imports for 70–90% of critical components like solar modules and advanced batteries exposes vulnerabilities to price volatility and supply chain disruptions. Addressing infrastructure gaps, reducing logistics costs, and boosting R&D can enhance cost efficiency and investment appeal.

Achieving Atmanirbharta in cleantech offers significant economic and strategic benefits, including job creation, reduced external dependencies, and a cost-effective transition to net-zero. By adopting an 'India Plus Many' strategy, India can strengthen its role in the global cleantech value chain, fostering energy security while contributing meaningfully to global net-zero ambitions.

20.Economist Impact, Scaling clean energy: financing and transition strategies for India's sustainable future, 2024
21.Bloomberg NEF, Energy Transition Investment trend, 2024
22. PIB, Ministry of New and Renewable Energy, 2023
23. Outlook Business, 2023; Ministry of Power, Report for Optimal Generation Capacity Mix for 2029-30, 2023

Potential opportunities and challenges

The opportunities to build a Viksit Atmanirbhar Bharat on cleantech supply chains include:

- Significant domestic market size of USD 120-150 Bn annually by 2030 in cleantech manufacturing
- Cumulative import bill savings of nearly USD 2 Tn by 2047 driven by reduced crude import[24] and further upside potential from reduced cleantech imports and accelerated adoption of decarbonized technologies
- Potential export opportunity of USD 40-45 Bn by 2030 (assuming 10% global export share), by leveraging 'India Plus Many' strategy.[25] For instance, India is the 4th largest exporter of wind-powered electric generators (USD 472 Mn) to ~20 countries, including major markets in Europe, Americas, and Australia.
- Creation of 50 million jobs in climate-technology and clean energy supply chains by 2070 [26]

Key challenges would have to be overcome to leverage these opportunities. Some of these challenges include:

- Indigenization at competitive costs to overcome / reduce production cost differences compared to China and other markets: This would require addressing challenges on infrastructure, raw materials, logistics and other costs as well to indigenize supply chains
- Financial barriers such as cost of capital, risk to return ratio for climate technologies in India need to be addressed to bridge the financing gap. Long-term financing instruments and innovative financing mechanisms could be incorporated to attract domestic and foreign capital
- Addressing workforce gaps through green skilling, specialized training and improving employability as well as sector attractiveness for skilled workforce is essential
- Increasing R&D and innovation investments to develop low-cost indigenous climate-tech suitable for India and ensuring stronger supply chain partnerships to drive adoption of innovation would support indigenization of cleantech supply chains at competitive costs. For instance, while SATAT guidelines targeted at increasing CBG production, the same has not ramped up in-line with targets and requires indigenous innovation suitable for Indian feedstock.

24.RMI, India at 2047,2024
25.Dalberg's analysis
26.Economic Times, India's transition to net zero economy can create over 50 million jobs, 2024

- Addressing raw material dependency and technology sharing from technologically advanced countries would be required to support indigenization. This could be enabled through stronger global partnerships

Key insights from panel discussion

The panel discussion focused on India's path to achieving net zero emissions through Atmanirbharta and fostering green energy innovation. Key themes included the importance of building domestic manufacturing capabilities in clean technologies, enhancing transmission infrastructure, and mobilizing capital to support the energy transition. The discussion also addressed the broader geopolitical and economic implications of India's renewable energy ambitions and highlighted the collaborative role of government, financial institutions, and private players in realizing these goals.

India's ambition to achieve Atmanirbharta in clean energy stems from strategic imperatives to reduce dependence on imports, such as from China, and establish itself as a global leader in green technologies. Panellists emphasized the importance of scaling domestic manufacturing in renewable energy components like solar modules, wind turbines, and batteries. While India currently faces cost disparities compared to global cleantech manufacturing leaders like China, the growth of an ecosystem with R&D investments, component manufacturing, and policy support will eventually close this gap. PLI schemes and a green industrial policy were identified as critical enablers for creating globally competitive manufacturing.

The panellists added that a robust transmission infrastructure is pivotal to ensuring the success of India's renewable energy goals. Without adequate grid connectivity, the transition to green energy cannot be fully realized. The discussion highlighted significant bottlenecks in the availability of high-quality Transmission and Distribution (T&D) components such as transformers, cables, and HVDC systems. The panel advocated for increased policy focus and fiscal incentives for domestic manufacturing in this segment, noting that transmission is often overlooked despite its critical role in delivering renewable energy to end-users.

The panel recognized the need for both domestic and international capital to support India's green energy ambitions. Financial institutions like SBI and Axis Bank are driving climate finance in India with initiatives such as green bonds, sustainability loans, and dedicated climate risk departments. However, regulatory barriers limiting pension and insurance funds from investing in green projects must be addressed. The Reserve Bank of India's recent initiatives, such as green deposit guidelines, are positive steps, but further reforms are needed to unlock significant domestic capital. Collaboration between public and private stakeholders is essential to ensure a steady flow of affordable capital into the sector.

India's green energy strategy is not just an environmental imperative but also an economic opportunity. India's energy transition offers a dual opportunity to grow sustainably while emerging as a leader for the global south in clean technology and green energy solutions. The transition to renewable energy will also drive substantial job creation, however, achieving this requires overcoming challenges related to land acquisition, policy ambiguity and limited long-term planning.

India's path to net zero through Atmanirbharta hinges on scaling clean energy manufacturing, strengthening transmission infrastructure, and mobilizing capital. The panel underscored the importance of consistent policy frameworks, industry-government collaboration, and global partnerships to realize this vision. By addressing existing challenges and leveraging its strengths, India is well-positioned to lead the global south in green technologies and establish itself as a hub for sustainable development.

FIRESIDE CHAT

ROLE OF GOVERNMENT IN ACCELERATING CLEANTECH MANUFACTURING IN INDIA

The fireside chat on **'Role of government in accelerating cleantech manufacturing in India'** was held between **Suresh Prabhu**, Former G20 Sherpa and Cabinet Minister of India (Commerce, Civil Aviation and others); **Shashank Mani**, Member of Parliament, Lok Sabha; **Ashwin Johar**, Member, IRBC, NITI Aayog; and **Erik Solheim**, Former Minister of Climate and the Environment of Norway; and was moderated by **Shirish Sinha**, Executive Director of Programmes, Clean Air Fund.

The chat focused on the government's role in advancing India's cleantech manufacturing through policy support, financial incentives, and international partnerships. It emphasized building a robust ecosystem, decentralizing solutions, strengthening supply chains, and leveraging India's cultural heritage to achieve self-reliance and global leadership in clean energy manufacturing.

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Context for the fireside chat

The fireside chat explored the critical role of government in fostering India's cleantech manufacturing ambitions amidst global and domestic challenges. Anchored on themes of policy coherence, financial incentives, and strategic partnerships, the discussion examined how India could leverage government initiatives like the PLI scheme to drive clean energy transitions. The session emphasized how indigenous manufacturing capacities for cleantech could help achieve the short-term and long-term commitments for a net-zero vision. Key questions included how government policies could catalyze private sector innovation and balance self-reliance with international partnerships. The speakers also highlighted the need to bridge gaps between national and state-level priorities while ensuring India's competitiveness in global supply chains.

Insights from the fireside chat

The discussion highlighted the critical need for a comprehensive ecosystem to support cleantech manufacturing in India. The speakers commented that, this ecosystem must go beyond financial incentives like the PLI scheme to include access to essential raw materials, advanced technology, and skilled human resources. The speakers emphasized the importance of backward integration, particularly in securing rare earth minerals required for manufacturing solar PV panels, battery cells and other renewable technologies. Strategic international partnerships and robust foreign policies were identified as vital aspects to ensure uninterrupted and stable supply chains, aligning with India's aspirations for self-reliance and global competitiveness in clean energy manufacturing.

Decentralization was identified as a transformative approach to addressing climate challenges and adopting low-carbon solutions. The speakers underscored the need to empower local institutions and communities to implement region-specific solutions. Examples included rooftop solar installations in densely populated areas and agri-solar systems in rural areas. They highlighted how decentralized models, like those in Germany, foster sustainable development by balancing urban and rural growth. By integrating India's cultural ethos—such as reverence for nature—into these strategies, public participation can be mobilized, creating solutions that are both environmentally sustainable and deeply rooted in local contexts.

The speakers stressed the need to strengthen supply chains at both local and global levels to make India a global leader in cleantech manufacturing. The suggested that, on the international front, foreign policy must focus on securing critical minerals from the Global North and South. Domestically, India must address inefficiencies in logistics and regulatory frameworks to support manufacturing growth. Examples such as Gujarat's streamlined renewable energy infrastructure were cited as successful models of effective governance. Balancing collaboration with and competition against global leaders like China, the speakers urged India to adopt lessons from their success in renewable energy value chains while carving its own path to cost competitiveness and innovation.

India's rich cultural and civilizational heritage was presented as a unique advantage in driving the cleantech transition. The speakers emphasized that ancient practices and values, which emphasize harmony with nature, can inspire modern approaches to sustainability. By showcasing India's civilizational ethos globally, the country can lead in not only clean technology manufacturing but also in demonstrating an integrated model of economic and ecological balance. This approach positions India as a thought leader in combining technology with cultural values to address global environmental challenges.

In conclusion, the speakers summarized that India's path to becoming a global leader in cleantech manufacturing hinges on a multi-pronged approach. They emphasized the need for a robust ecosystem that integrates policy support, international partnerships, and localized solutions. Securing access to critical raw materials, fostering decentralization, and addressing inefficiencies in logistics and governance are vital to achieving self-reliance and cost competitiveness. Additionally, leveraging India's cultural heritage to inspire sustainability and embedding these values in policy frameworks can amplify its global leadership in cleantech. Achieving this vision requires a coordinated effort from the government, industry, and communities to align ambition with action.

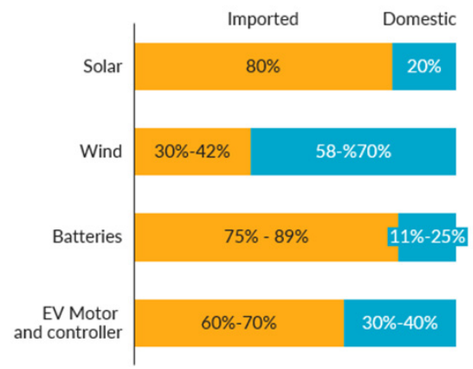
DELIVERING ON THE TRANSITION: CAN BHARAT BECOME COST-COMPETITIVE BY INDIGENIZING CLEAN TECH MANUFACTURING?

The panel discussion on **'Delivering on the Transition: Can Bharat Become Cost-Competitive by Indigenizing Cleantech Manufacturing?'** was held between **Girish Tanti,** Co-founder, Suzlon India; **Gyanesh Chaudhary,** CMD, Vikram Solar; **Vineet Mittal,** Chairman, Avaada Group; **Bhupinder Singh Bhalla,** Former Secretary, MNRE; **Jon Creyts,** CEO, Rocky Mountain Institute; and **Nagesh Kumar,** Director and Chief Executive, Institute for Studies in Industrial Development (ISID); and was moderated by **Ila Patnaik,** Chief Economist, Aditya Birla Group.
The keynote speaker, **Amitabh Kant,** India's G20 Sherpa, also presided over the panel.

Context and rationale

India imports 70-90% of cleantech components and parts used in clean energy and green mobility applications, except for the wind energy sector, with 30-42% imports.[27] While the announced renewable energy capacity in 2030 (which includes ~300 GW solar, ~100 GW wind, and ~15 GW bioenergy approximately) appears sufficient to meet the government's 500 GW non-fossil energy installed capacity target, achieving cost competitiveness for this capacity will be critical for the indigenization of the supply chain.[28] For other sectors, the projected capacity of 140 GWh for Battery Energy Storage Systems (BESS) would only meet 78% of the demand for EV batteries and power storage in the same year, highlighting the need to scale domestic production at competitive costs to reduce dependence on imports.[29]

Figure 5: Cleantech manufacturing import dependence across the value chain, 2023



27.CEEW, Strengthen India's Clean supply chain, 2024; Bain, India Electric Vehicle Report, 2023; Policy circle
28.BNEF, Announced capacity of wind, solar and hydro power
29.BNEF, Announced capacity data of battery

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While India exhibits cost competitiveness compared to the EU and US, with Western countries facing production costs 6-41% higher, a significant gap remains with China (20-47% lower costs than India)[30] (Figure 6). This gap must be bridged to compete globally and successfully leverage an 'India Plus Many' strategy.

China's exceptionally low costs are primarily driven by large-scale subsidies and significant government support, which may be difficult for other countries to emulate. However, improved cost competitiveness in India could increase its potential as a cleantech hub.

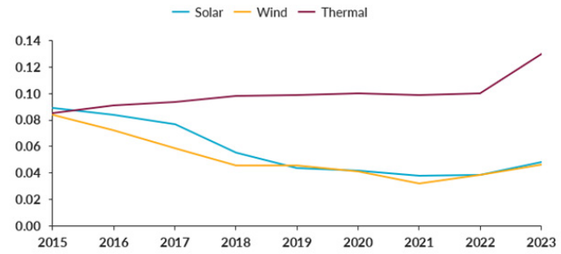
Further, as demand for cleantech manufacturing increases in India, cost advantages would be imperative for adoption—compared to both landed imported costs and fossil fuel technologies. While import dependence drives price fluctuations in India driven by global market dynamics, a low to no cost advantage compared to fossil fuels is detrimental to India's net zero transition.

Figure 6: Cleantech cost comparison between India and other countries (India price = Index 100%)

	EU / US	China
Solar	126%	80%
Wind	122%	63%
Batteries	106%	76%
Electrolyzers	141%	70%

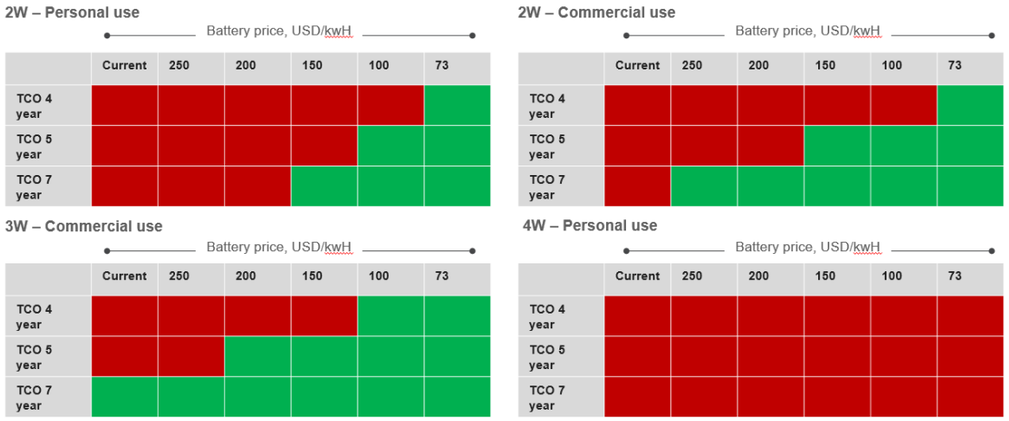
The current cost comparison of cleantech manufacturing or the cost of energy production from clean energy compared to fossil fuels also indicates the impact of high import dependence and the cost gap that needs to be bridged to accelerate cleantech adoption in India. For instance, while LCOE for solar energy is now lower than thermal energy in India (Figure 7)[31], indigenization at current costs (~20% higher than China) could increase CAPEX costs for solar power plants by ~12%, leading to a 9-10% potential increase on LCOE for solar power (even at 80% indigenous supply chains).[32] For other sectors, bridging the gap between cleantech costs and fossil fuel technologies could significantly accelerate the adoption of cleantech to drive the net zero transition. For example, Figure 8 shows that TCO (5-year) for electric two-wheelers will be attractive only if battery price reduces to below USD 100 per kWh, whereas, with current policies and benefits, passenger electric four-wheelers won't achieve commercial viability even at USD 73 per kWh battery prices.[33] Similarly, there are cost gaps for green fuels, with green hydrogen being 2.5 times more expensive than grey hydrogen, indicating the need for cost-competitive indigenization of the entire value chain to drive adoption.[34]

Figure 7: LCOE (levelized cost of energy) for electricity generation in India, USD / kWh



27.CEEW, Strengthen India's Clean supply chain, 2024; Bain, India Electric Vehicle Report, 2023; Policy circle
28.BNEF, Announced capacity of wind, solar and hydro power
29.BNEF, Announced capacity data of battery
30.IEA, Advancing Clean Technology Manufacturing, 2023;
31.IRENA, Renewable Power Generation cost, 2023
32.Dalberg's analysis
33.SIAM, Adopting Pure Electric Vehicles: Key Policy Enabler, 2017
34.ORF America, India's Role in Diversifying Global Clean Energy Supply Chains, 2024

Figure 8: Total cost of ownership attractiveness by type of vehicle



Potential opportunities and challenges

The opportunities for driving cost-competitive indigenization of cleantech value chains in India are clear in terms of:

- Significant domestic market size of USD 120-150 Bn annually by 2030[35]
- Cumulative import bill savings of nearly USD 2,000 Bn from 2024 to 2047 driven by reduced crude import and further upside potential from reduced cleantech imports and accelerated adoption of decarbonized technologies[36]
- Potential export opportunity of USD 40-45 Bn annually by 2030, assuming 10% global export share[37]

The challenges to addressing these opportunities exist both at macroeconomic levels across sectors and cleantech-specific challenges:

- Macroeconomic factors impact the growth of nascent sectors in India more than large, established sectors. Factors such as infrastructure gaps, high logistics costs, logistical inefficiencies, ease of doing business constraints and local implementation-related issues impact hinder cleantech investments in India
- Cleantech-specific challenges which eventually impact the cost competitiveness for cleantech manufacturing in India include:
  - **Raw material availability** challenges with India having limited sources of rare earth materials, which are crucial for cleantech manufacturing
  - **Higher energy costs** for both electricity and fuel for India compared to China and Middle Eastern countries, limiting the cost-benefit for sectors utilizing commercial power for cleantech manufacturing
  - **Technical expertise and specialized workforce to drive design and innovation.** This lack of expertise often results in reliance on foreign consultants or collaborations, increasing costs and extending project timelines
  - **Limited R&D investments.** Insufficient funding for research and development (R&D) in the cleantech sector has hindered India's ability to innovate and create indigenous technologies. As a result, domestic manufacturers often rely on importing designs, technologies, or partially assembled components from other countries
  - **High cost of skilled workforce due to demand-supply gap.** This demand-supply imbalance is particularly acute for roles requiring high technical skills, making it costlier to execute projects domestically compared to countries with better workforce alignment
  - **Dependence on China for machinery and equipment.** This dependence limits India's ability to scale its manufacturing capacity quickly and exposes the industry to supply disruptions and geopolitical risks. Additionally, the lack of domestic production capabilities for these machines increases overall costs and delays in project execution

The above factors may not impact India's cost competitiveness potential equally and addressing the most relevant and impactful factors first could step-change the pace of cleantech expansion in India while reducing costs.

35.Dalberg's analysis
36.RMI, India at 2047, 2024
37.Dalberg's analysis

Bharat Climate Forum 2025

Keynote address

Shri Amitabh Kant, India's G20 Sherpa, delivered an enthralling keynote address at the Bharat Climate Forum, emphasizing the urgency of advancing cleantech manufacturing in India. He began by framing the discussion within the context of India's goal to achieve net-zero emissions by 2070 and its aspiration to become a USD 30 Tn economy. Highlighting India's heavy reliance on imported cleantech components, particularly from China, he underscored the geopolitical and economic implications of this dependency. The address set the tone for a focused discourse on the challenges India faces and the strategic actions required to position itself as a global leader in cleantech.

Shri Amitabh Kant added that India's reliance on imports for critical cleantech components is one of the most significant challenges to self-reliance. He revealed startling figures: 80% of solar PV components, 85% of batteries, and 65% of EV motors used in India are imported, with China dominating 70-85% of global market share in these areas. He emphasized that this dependence not only threatens India's energy security but also limits its ability to scale domestic industries and compete globally.

To counter this, he stressed the need for technological leapfrogging and innovation. He highlighted India's unique advantage of favourable political and economic conditions towards cleantech adoption, which could reduce the level of subsidization required compared to Western nations. India must capitalize on emerging technologies like sodium-ion and aluminium-ion batteries, where it can avoid the costly groundwork already undertaken by China. He pointed to the promising role of startups in adopting cutting-edge technologies, citing examples like Log9, Ion Energy, LOHUM and Godi Energy.

The speech also underscored the importance of building a circular economy and investing in waste processing as critical enablers of India's cleantech ambitions. Shri Amitabh Kant noted that startups focusing on battery recycling and energy efficiency are key to reducing waste and ensuring resource sustainability. Furthermore, he called for greater financial support for these initiatives, advocating for increased credit flow from private institutions, insurance companies, and pension funds, as India's private credit-to-GDP ratio remains significantly lower than that of global peers.

Shri Amitabh Kant concluded with a strong call to action, emphasizing that India's journey to becoming a Viksit Bharat and achieving net-zero emissions by 2070 depends on its ability to indigenize cleantech manufacturing. By leveraging its unique strengths, fostering innovation, and ensuring robust policy and financial support, India can transform its cleantech sector into a global powerhouse. This transformation, he emphasized, is not just an opportunity but an imperative to secure India's economic future and its position as a global leader in clean energy.

Key insights from panel discussion

The panel discussion centred around India's significant reliance on imported cleantech components, between 60% to 90% across most sectors. Though India compares favourably to the US and EU on cost-competitiveness, it lags far behind China, which benefits from extensive subsidies and economies of scale. The panel aimed to address critical challenges such as infrastructure deficits, high logistics and energy costs, policy uncertainty, and the need for backward integration in cleantech manufacturing. It also explored sector-specific challenges, including critical minerals, mining policy, and dependency on foreign machinery, particularly from China. Framed within the opportunities presented by India's large domestic market and growing energy demands, the discussion sought to uncover lessons from successful sectors and identify actionable strategies for achieving cost competitiveness and self-reliance in cleantech manufacturing.

India's import dependence for cleantech components, ranging from 60% to 90% in most sectors,[38],[39],[40] underlines the critical need for cost competitiveness. While India is relatively competitive compared to the US and EU, it struggles to match China's low costs driven by economies of scale, government subsidies, and strategic investment in manufacturing ecosystems. The panel emphasized that achieving cost competitiveness is essential not only for reducing import dependency but also for positioning India as a global supplier of cleantech components. This requires a clear focus on policy coherence, infrastructure improvements, and scaling domestic production capabilities.

India's renewable energy targets demand a rapid increase in scaling manufacturing capacity, particularly in solar and wind components. The discussion highlighted that despite recent progress—such as increasing module manufacturing capacity to 63 GW[41] – there are substantial gaps in integrated manufacturing, including wafer and polysilicon production. Addressing bottlenecks like land acquisition, evacuation infrastructure, and supply chain inefficiencies was observed as a critical enabler to drive scale and efficiency. Furthermore, participants stressed the need for harmonized policies between wind and solar energy to prevent stagnation or decline in sectors like wind manufacturing, where local content has fallen in recent years.

Innovation and R&D were identified as pivotal for India's cleantech sector to compete globally. While India's investment in R&D remains significantly lower than global leaders,[42] the panel recognized an opportunity to leapfrog through emerging technologies such as sodium-ion and solid-state batteries. The discussion also highlighted the need for greater private sector participation in R&D investments. Leveraging geopolitical shifts, India could combine its manufacturing strengths with advanced technology from leading cleantech manufacturing nations to meet both domestic and global cleantech demand. This partnership approach could enable India to reduce its dependency on China while capturing export markets.

The panel underscored the importance of demand and supply-side interventions to boost cleantech manufacturing. Policies like Production Linked Incentive (PLI) schemes and measures like the Authorized List of Manufacturers and Modules (ALMM) were recognized as crucial for fostering domestic manufacturing. However, the need for predictability and consistency in policy frameworks was stressed to attract private investment. Additionally, creating a collaborative ecosystem where government support, private enterprise, and research institutions work in tandem was deemed essential for building a resilient cleantech manufacturing base.

In conclusion, the panel emphasized that India's success in becoming a cost-competitive cleantech manufacturing hub relies on addressing structural challenges like infrastructure, policy coherence, and integrated manufacturing capacity while leveraging its entrepreneurial and innovation strengths. A clear call was made for increased investment in R&D and emerging technologies to reduce import dependence and achieve technological leadership. Collaboration between government, industry, and research institutions is essential to harmonize policies, scale production, and foster innovation. Cleantech manufacturing was framed not only as an economic opportunity but as a strategic imperative to enhance energy security, create jobs, and position India as a global leader in cleantech.

38.EV Reporter, India's Electric Vehicle supply chain landscape, 2024
39.Policy Circle, India's solar industry must break free from Chinese dependence, 2024
40.CEEW, How Can India Indigenise Lithium-Ion Battery Manufacturing? 2023
41.PV Magazine, India reaches 63 GW of annual PV module manufacturing capacity, 2024
42.Ministry of Education, Expenditure on Research and Development, 2023

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STRENGTHENING BHARAT'S CLEANTECH AND MANUFACTURING ECOSYSTEM: CONNECTING IDEAS, INNOVATION, AND INDUSTRY

The panel discussion on **'Strengthening Bharat's Cleantech and Manufacturing Ecosystem: Connecting Ideas, Innovation, and Industry'** was held between **Anjali Bansal,** Founding Partner, Avaana Capital; **Amit Singh,** Chief Executive Officer, Adani Green Energy Ltd; **Prof. Ambuj Sagar,** Vipula and Mahesh Chaturvedi Professor of Policy Studies, IIT Delhi; **Hemang Jani,** Senior Advisor to the Indian Executive Director at the World Bank Group, and Board Member of Atal Innovation Mission, India; and **Sangeeta Kaushik,** Executive Director, NTPC; and was moderated by **Dhruba Purkayastha,** Director for Growth and Institutional Advancement, Council on Energy, Environment and Water (CEEW).

Context and rationale

Globally, several countries are at the forefront of climate tech innovation, each contributing uniquely to the global transition towards sustainable technologies. While China has emerged as a leader in cleantech manufacturing and deployment, the U.S. maintains a strong position in cleantech innovation, particularly in regions like Silicon Valley driven by a strong venture capital landscape and emphasis on

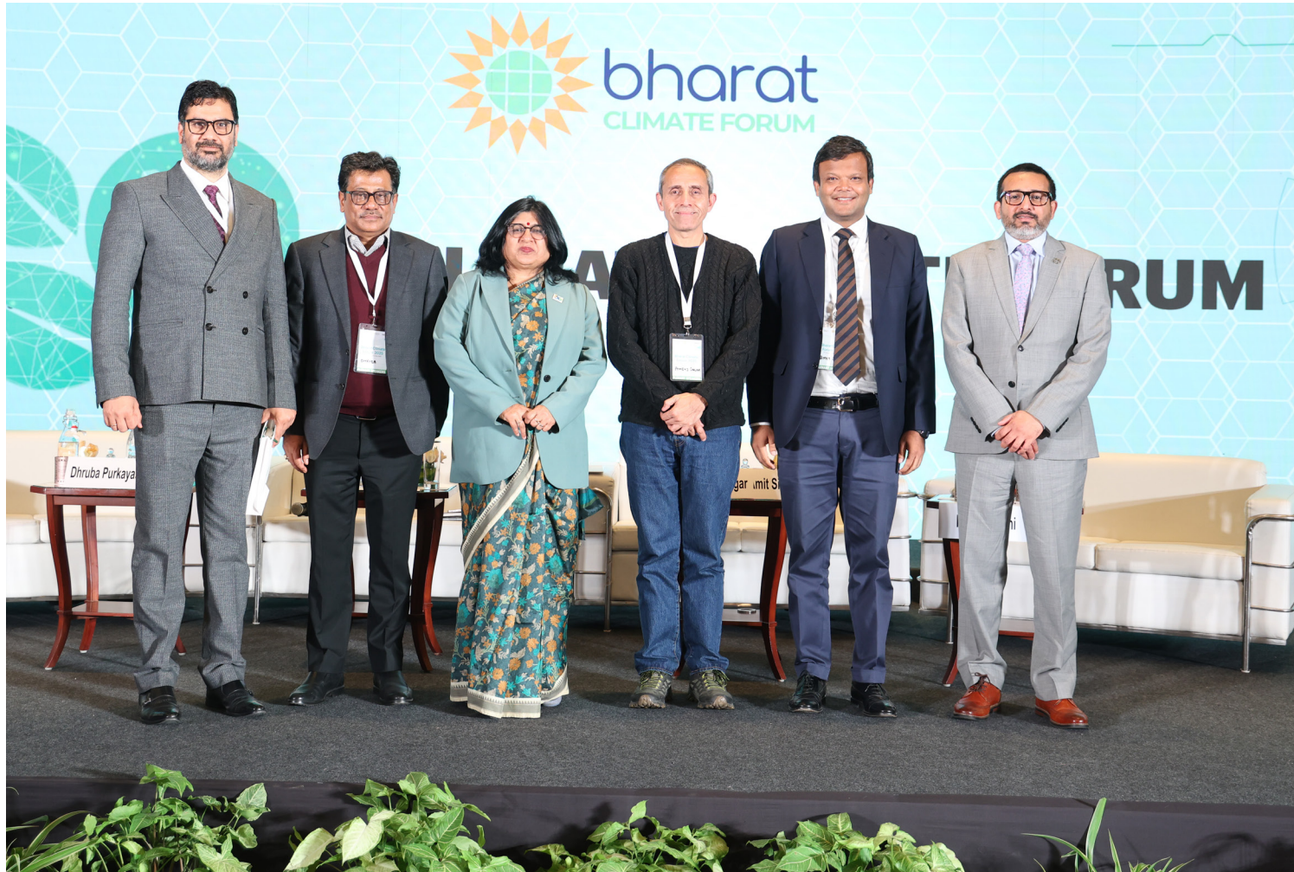
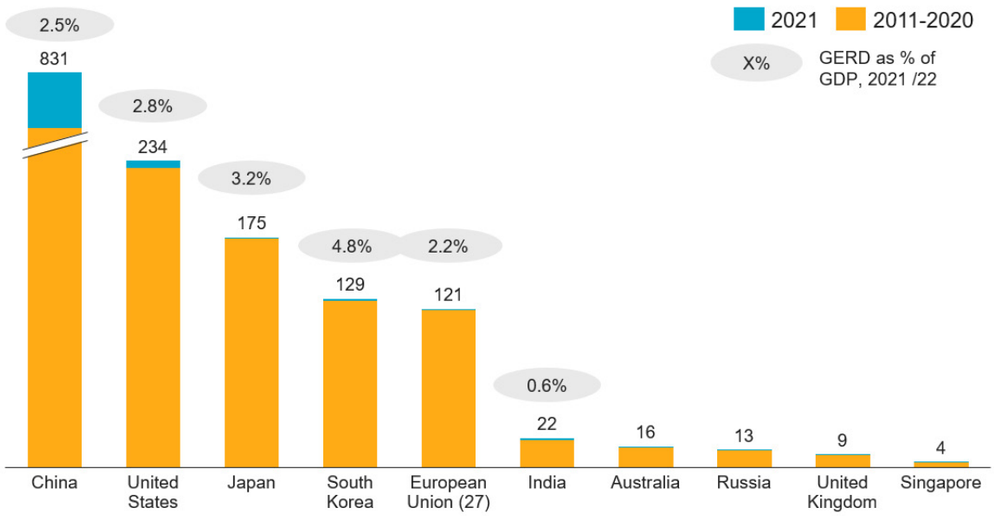


Figure 9: Gross Expenditure on R&D (GERD as % of GDP) and number of renewable energy e-mobility and energy storage patents filed by country, 2011-2021, '000 patents



research and development. Canada ranks second on the Global Cleantech Innovation Index 2021, trailing only the U.S. with numerous cleantech companies across sectors such as energy, power, resources, environment, and transportation. China, US, Japan, South Korea and EU-27 invest 2-5% of GDP in R&D, compared to 0.6% in India,[43] and have also filed ~90% of patents globally in renewable energy, energy storage and e-mobility as shown in Figure 9.

Figure 9: Gross Expenditure on R&D (GERD as % of GDP) and number of renewable energy e-mobility and energy storage patents filed by country, 2011-2021, '000 patents

Innovation is encouraged through various avenues in countries such as US, UK, Canada, EU-27 and Australia through a relatively higher R&D investment in educational institutions in the range of up to 14-18% of total revenue. Most leading universities and educational institutions in these countries have dedicated start-up incubation centres and strong connections or funding initiatives. Some of the latest innovations from these educational institutions include, a non-flammable, nontoxic solution battery solution to replace lithium-ion with stable, abundant materials and a primarily water-based electrolyte[44] (at a start-up co-founded by MIT Professor Kripa Varanasi); an 'ultra-thin material' that provides 27% energy efficiency in converting sunlight into energy, exceeding the current efficiency of 23%[45] (by Oxford University researchers); ceramic electrolysis cells featuring Ni-GDC fuel electrodes that maintain performance without degradation over 1,000 hours of testing and could potentially reduce green hydrogen production costs by up to 5%[46] (by Technical University of Denmark (DTU) researchers).

Moreover, leading private sector companies in these countries also invest heavily on R&D – automotive companies in China, US and EU invest 1.8-6.3% of revenue in R&D as compared to 2-3% in India in 2023 (except for Mahindra and Mahindra at 5.7%).[47] This has fueled innovations in the cleantech sectors, such as China leading innovations in EV and battery industry with Blade Battery design by BYD motors which is now widely adopted by multiple OEMs including Tesla and Mahindra. In addition, Chinese companies like Zeekr and CATL have recently unveiled batteries that can charge to 80% in just over 10 minutes.[48] In Scotland, Celtic Renewables has developed a patented technology that converts whisky by-products into biobutanol—a sustainable biofuel that can serve as a direct replacement for fossil fuel.[49] Also, in the UK, a company named Space Solar has secured a deal with Reykjavík Energy to develop space-based solar power systems, enabling the transmission of renewable energy from solar panels in space to Earth.[50]

Supportive policies, such as the Inflation Reduction Act in the US[51] promoting adoption of climate solutions and favourable infrastructure, such as integrated supply chains and strong value chain partnerships fuel innovation, improve ease of doing business and encourage investments in startups from early stages to maturity in these countries. The top 10 for Ease of Doing business ranking comprises the United States, the United Kingdom, major European Union countries, China, and leading Asian economies such as Singapore and South Korea[52] which strongly co-relates with the number of cleantech patents from these countries.

In India, there has been an increase in climate-tech startups with VC/PE investments in climate startups increasing at 33.87% CAGR[53] between 2018-2023, with 94%[54] of total climate-tech investments between 2019 and 2023 going into the renewable energy, e-mobility and energy storage sectors. These investments have supported startups such as Ola, Ather, PureEV and others in the EV space who have indigenized 70% of electric 2W production in India and are leading Atmanirbhar Bharat for cleantech manufacturing by example. Innovation across the e-mobility value chain is also being driven by startups, for instance with Log9 materials on battery cell, anode and pack production as well as battery recycling startups to manage end of life. While such investments clearly indicate an intent to support innovation in India, the number of and scale-up for such startups could be accelerated through supportive infrastructure and policies.

However, India's Gross Expenditure on Research and Development (GERD) has been relatively low, consistently around 0.6% of GDP (compared to 2.4% of GDP in China and 3.1% of GDP in Germany) and needs to increase considerable to fuel innovation. There are green shoots in this regard with increased investments in leading educational institutions on R&D, government support on startup incubation through initiatives like Atal Innovation Mission and public-private partnerships such as Startup India through Invest India and DPIIT to build a supportive startup ecosystem and fuel innovation.

Leading educational institutions have set up incubation centres and increased their R&D funding in recent years. Government support fuels this through the Institutes of Eminence (IoE) scheme which was launched to empower selected higher education institutions, including IITs, with greater autonomy and funding. IITs under this scheme receive enhanced financial support of up to USD 116 Mn (INR 1,000 crore) each over five years, enabling them to strengthen research, innovation, and global competitiveness. The initiative aims to position Indian institutions among the top 500 globally and foster excellence in education and research.

43.Department of Science and Technology (DST), Government of India, R&D Statistics at a Glance 2022-23
44.TIME magazine, 2024
45.Yahoo Tech, 2024
46.DTU University, 2024
47.Financial express, Wards Auto, Statista, Finbox
48.Business Insider, 2024
49. Scottish Development International, 2024
50.The Times, 2024
51.The Trump Administration has issued an Executive Order to repeal the IRA
52. Ease of Doing business ranking, World Bank, 2020
53.The Secretariat, India's Climate Tech Startups The New Darlings of VCs, Funders
54.Green Frontier Capital, Climate VC Fund: Driving Climate Tech Investments

Recent changes in policies and startup infrastructure in India have led to the establishment of over 1100 startup incubation centres in India. Initiatives such as the Atal Innovation Mission (AIM) support startups in India by establishing incubation centres, providing funding, mentorship, and market linkages to foster innovation. Announcements such as 'Jai Anusandhan' Scheme which will provide long-term, interest-free loans to private entities to support R&D projects are required in climate-tech sectors as well to support and grow this startup infrastructure.

Scaling-up of such initiatives and an expansive startup incubation infrastructure is required at a large scale in India to foster a culture of innovation. Ensuring adoption of indigenous innovations needs to be further driven through both government and private sector support. Limited R&D investment from leading private sector companies (1.8-6.3% of revenue) in India leads to slower adoption and lesser innovation from large companies. Often this leads to acquisition of scaling-up startups but does not foster a culture for innovation within large companies. Lastly, infrastructural and implementation challenges for small businesses impede the investment attractiveness and scale-up opportunities for climate startups.

Today, very few startup incubation centres are focused on climate technologies as evident from the number of climate-tech startups (estimated at 3300[55]) compared to total number of startups in India (over 150,000[56]) indicating the need to drive climate-tech focused innovation through the incubation infrastructure. While there is a growing trend of climate-tech innovation in India, exemplified by the 22,000 patents granted between 2016-2021 to alternative energy production, energy conservation, transportation technologies and nuclear power generation, further acceleration is warranted. With the right support and infrastructure, these innovations could support indigenization of climate technologies in India and help build an Atmanirbhar Bharat for cleantech manufacturing.

Potential opportunities and challenges

India could accelerate net-zero transition through indigenous innovations by increasing R&D investments to capture opportunities such as:

- Lower cost and faster pace of indigenous cleantech manufacturing through low-cost technologies and solutions developed in India, for India
- Low-cost designs and innovative designs using locally available materials to meet economic thresholds, particularly for battery packs, energy storage, hydrogen electrolyzers
- Creating 100+ climate-tech unicorns in India: Today India has 117 overall unicorns, with very few climate unicorns. Accelerating innovation and adoption of indigenously developed climate-tech could help create a thriving startup ecosystem and build climate unicorns

There are myriad challenges that need to be overcome to capture these opportunities. Some of these challenges include:

- Limited private sector funding in R&D and innovation: Majority of R&D expenditure if borne by the government in India through educational and research institutions and grants indicating a need to increase private sector involvement financially and technologically
- Long lead time for initial innovations could impact speed to market vs. global tech adoption
- Diverse and complex supply chain partnerships hinder quick adoption of new innovations. Stronger collaboration across supply chains is required to accelerate adoption
- Bridging both specialized skill gaps and financing gaps are crucial to build a thriving climate startup ecosystem

Key insights from panel discussion

Participants discussed critical gaps and opportunities in fostering India's cleantech innovation ecosystem, emphasizing the roles of capital, industry-academia linkages, and tailored government policies. A key theme was the need to define an enabling environment for innovation, particularly in the context of India's dual challenge of achieving economic growth while addressing climate change and transitioning to net zero emissions. Participants highlighted the importance of scaling cleantech manufacturing, accelerated deployment of commercialized innovations, and fostering deeper collaborations among industry, academia, and policymakers.

Panellists noted that India's emerging entrepreneurial talent and innovators from across the country and beyond metro cities as well, were actively engaging in sectors like clean energy, water, circular economy, waste-to-fuel and waste-to-energy, and agriculture. However, several gaps were identified, including inadequate early-stage capital for startups, and weak industry-academia linkages. Participants pointed out the absence of systemic mechanisms to support the transition of innovations from prototype stages to large-scale commercialization. They noted that while some progress has been made through pilot projects and shared infrastructure, further efforts are required to ensure startups can meet the scale demands of larger industries. Participants observed that India's R&D investment remains below 1% of GDP (at 0.6% of GDP),[57] with corporate contributions being particularly low. They emphasized that industry, academia and policymakers need to better align their priorities and resources to address this shortfall, highlighting the role of the government as a key enabler.

The panel emphasized the need for advancements in specific segments such as battery storage systems and climate modelling to optimize renewable energy deployment. They called for sustained, strategic relationships between universities and industries, suggesting that co-located research facilities could foster innovation through continuous interaction. Government representatives and policymakers were urged to provide tailored support across the innovation cycle, from R&D to deployment, and to leverage global knowledge for localized solutions.

The discussion also highlighted the role of multilateral institutions in bridging knowledge gaps and offering technical expertise. Participants noted that such institutions could provide concessional funding and be valuable knowledge partners, particularly in understanding global best practices and customizing them for local contexts. The role of large public sector entities was also highlighted as pivotal in driving pilot projects, such as green hydrogen initiatives. However, participants noted challenges in scaling and commercialising these efforts due to cost barriers and market limitations.

Some possible solutions to drive innovation discussed by the panel members included creating shared infrastructure for deep tech manufacturing, enhancing industry participation in innovation parks, and establishing think tanks to facilitate the commercialization of developed technologies. Additionally, participants proposed fostering cross-sectoral collaboration and exploring knowledge exchanges with other global south economies to enrich India's innovation landscape.

The session concluded with panellists urging stakeholders to address capital shortages, improve prototype scalability, and strengthen the synergy between academia, industry, and government. Participants advocated for tailored support for diverse technologies and stages of the innovation cycle to ensure sustainable and scalable solutions for India's cleantech future.

55. EAI, India has over 3000 climate tech startups, 2024
56. Fortune India, Startups in India has risen three-fold in 5 years, 2024
57. Ministry of Education, Expenditure on Research and Development, 2023

PATHWAYS FOR INDIA'S TRANSITION TO GREEN MOBILITY: ROLE OF HYBRID VS. EVs AND OTHER TECHNOLOGIES

The panel discussion on **'Pathways for India's transition to green mobility: Role of Hybrid vs. EVs and other technologies'** was held between **Anand Kulkarni,** Chief Product Officer, Passenger Electric Vehicle, Tata Motors; **Abanti Sankaranarayanan,** Chief Group Public Affairs Officer and a Member of the Group Executive Board of Mahindra and Mahindra Ltd.; and **Anirudh Arun,** Co-Founder and CEO, Blu-Smart; and was moderated by **Mahua Acharya,** Founder – INTENT, Ex-MD and Ex-CEO, CESL.

Context and rationale

Net-zero commitments are beginning to drive the shift in road transport due to the sector contributing 17% to global CO2 emissions.[58] with technologies such as electric vehicles (EVs), hybrid vehicles, and fuel-cell vehicles (FECVs) representing key pathways in this journey. Most high-emitting countries have set net-zero targets and commitments, with specific targets for the road transport sector, such as the EU's targets of reducing the sector's emissions by 40% by 2030 and having 100% of new cars sold have zero CO2 emissions by 2035, China's EV target of 45% of new car sales in 2027.[59]

EVs (including BEV – 70%[60] and PHEV—30%) accounted for 18% of global car sales in 2023, a 35% increase from the previous year, reaching nearly 14 million units and 40 million on the road. This growth was largely driven by China, Europe, and the United States, which represented 95% of global electric car sales. Hybrid vehicles grew by 24% year-on-year due to fuel efficiency and reduced emissions benefits, making up 6.7% of passenger car sales globally. [61]

Figure 10: Share of EVs in new car sales by country, 2022 vs. 2023

Subsidies have been critical in driving EV adoption, especially in bridging cost differences with ICE vehicles. For instance, over 60% of EVs sold in China in 2023 were cheaper than ICE alternatives.[62] supported by government policies, competitive markets, and low battery costs.[63] Countries like Germany[64] and South Korea[65] have begun phasing out subsidies. The decline in EV sales in Germany after the subsidies were removed highlights the need for cautious transitions to sustain adoption.

India has also committed to transition towards green mobility with its 30@30 target of having at least 30% of new vehicle sales be electric by 2030.[66] As illustrated in Figure 11, 3-wheelers are the only category where significant penetration has been made and have the most favourable TCO. 2-wheelers, the

Figure 11: New vehicle sales by category and drivetrain in India, 2023 (Mn vehicles)

Figure 12: Total Cost of Ownership (TCO) Attractiveness, assessed by Payback for EV usage (in years), by type of vehicle

58.SIAM, Annual Report, 2023

59.Rystad Energy, Report, 2024
60.EV Volumes, Global EV Sales for 2023, 2023
61. BNEF, Long-Term Electric Vehicle Outlook, 2024
62.Ibid
63.MIT Technology Review, How did China come to dominate the world of electric cars? 2023
64.MIT Technology Review, Some countries are ending support for EVs. Is it too soon?, 2024
65.Korea Herald, South Korea to lower EV subsidies by W1m, 2024
66.MyGov.in, Driving into the Future, 2021
67.Times of India, Press Report, 2024
68.Bajaj Allianz, Company Website, 2024
69.ET Auto, Press Report, 2024
70.CNBC, Press Report, 2024



largest segment of vehicles, have only 6% penetration, with prospective buyers facing issues related to motor vehicle loans, lower levels of financing,[67] higher insurance premiums[68] and service-related issues.[69] 4-wheelers have even lower EV penetration and face a higher TCO than ICE and Hybrids.

Hybrid vehicles are becoming more attractive, and they are taking advantage of slowing BEV sales to narrow the sales gap. Between January and July 2024, 51,832 units were sold, compared to 54,118 BEVs in the same period.[70] This shift in consumer preference seems to be driven by hybrids' lower upfront costs and fewer concerns about driving range, charging infrastructure, and resale value.[71] OEMs are launching either EVs or Hybrids, with Tata Motors and Mahindra & Mahindra dominating EVs and Toyota, Maruti Suzuki, and Honda leading in hybrids. However, it remains to be seen whether this trend will continue.

FCEVs are at a nascent stage and would need cost-competitive green hydrogen costs to scale adoption. They have significant potential in commercial and heavy vehicles, outperforming BEVs in terms of driving range, refueling time, and environmental impact, albeit with a higher TCO.[72] With investments from Tata Motors and Ashok Leyland in fuel-cell buses and HCVs and support from the National Green Hydrogen Mission, hydrogen could power as much as 10-15% of India's HCVs by 2030.[73]

Each technology has a role in India's transport sector decarbonization pathways, including in the short and long term. Policymakers, automobile manufacturers, investors, and other stakeholders must collaborate to develop an integrated roadmap for a sustainable road transport sector.

Potential opportunities and challenges

The opportunities for driving the transition towards green mobility in India are clear in terms of:

- Significant domestic market size of USD 53-57 Bn by 2030, assuming 30% low carbon mobility penetration and CAGR of 5-6% for the automobile sector with 100% indigenization
- Import bill savings of up to USD 21-23 Bn annually by 2030 driven by increasing indigenization of EV components and manufacturing to 80% and accelerated adoption of decarbonized technologies. A cumulative USD 1.8-2 Tn savings with reduced petroleum imports between 2024 and 2047[74] is also feasible with the increased adoption of low-carbon mobility in India
- Potential to become a major player in the global EV market, with India's cumulative export potential estimated at USD 336 Bn between 2024 and 2047[75]

The challenges to addressing these opportunities exist both at macroeconomic levels across sectors and green mobility-specific challenges:

- Macroeconomic factors impact the growth of nascent sectors in India more than large, established sectors. Factors such as infrastructure gaps, high logistics costs, logistical inefficiencies, and local implementation issues hinder scaling-up investments in manufacturing India
- Coal heavy power generation mix results in significant emissions for EVs, reducing the impact of electrification and making hybrid vehicles more attractive
- Green mobility-specific challenges which eventually impact the cost competitiveness for EV, hybrid, fuel cell, and other green mobility-related manufacturing in India include:
  - High upfront cost of EVs may lead to dependence on subsidies to drive adoption
  - Limited charging infrastructure inhibiting EV adoption
  - Raw material availability, continued dependence on imports and global supply chain issues
  - Technical expertise and specialized workforce required to drive design and innovation
  - Dependence on global designs and production for components
  - High cost of skilled workforce due to demand-supply gap
  - Dependence on China for machinery and equipment, limiting pace and cost of expansion

The above factors may not impact green mobility transformation in India equally and addressing the most relevant and impactful factors first could step-change the pace of this transition while reducing costs.

Key insights from panel discussion

Participants discussed India's transition to EVs, focusing on opportunities, challenges, and strategies to accelerate adoption while fostering sustainability and economic growth. They began by addressing India's pressing mobility needs, highlighting issues such as high traffic density, severe air pollution, and the country's growing automotive market, which contributes to both economic development and environmental concerns. Panellists noted the significant growth of the EV market in India, with current monthly sales of EV passenger vehicles close to 10,000 units,[76] and emphasized that EVs represent the optimal solution to mitigate these challenges, bypassing transitional technologies like hybrids and directly pursuing carbon neutrality and pollution reduction goals.

Speakers compared India's strategy to global examples, such as China's support for EVs, which accelerated its position as a global leader in clean mobility. They also emphasized that while hybrids initially offered a stepping stone for economies like the EU and the US, these nations show signs of pivoting towards fully electric solutions[77] to meet their climate goals. India's decision to leapfrog directly to EVs was viewed as a strategic enabler fuelling rapid progress towards sustainability and economic growth.

The discussion also addressed challenges such as workforce transition, cost disparities, and infrastructure. Participants acknowledged that transitioning from internal combustion engine (ICE) to EV production has posed workforce concerns. However, they highlighted opportunities for retraining and localizing EV-related industries, including battery production and power electronics, which could create a robust ecosystem of jobs and investments. Range anxiety and the high upfront cost of EVs continue to be hurdles for EV adoption, but panellists noted advancements in technology and charging infrastructure that are mitigating these concerns.

Speakers also stressed the importance of localization and innovation in battery technology to reduce costs and increase accessibility. They pointed to recent progress in battery manufacturing under India's Production-Linked Incentive (PLI) scheme and projected further declines in battery costs, enabling wider adoption across vehicle segments. Participants also agreed that efforts needed to be made to reduce non-cell costs, so that the overall costs of EVs would be comparable to ICE alternatives.

Panellists noted that range anxiety, which was initially a significant barrier to adoption, is being mitigated by improved battery capacity and the expansion of charging infrastructure. Participants pointed to collaborations between OEMs, private players, and the government to develop public charging networks and promote private charging solutions for homes and offices. Government measures like the setting up of 22,000 public charging stations by PSU Oil Marketing Companies[78] were recognized as a vital step forward.

Participants outlined several forward-looking priorities for the EV industry, including product innovation, infrastructure development, and consumer adoption. They emphasized the importance of developing vehicles with higher ranges, faster charging capabilities, and enhanced safety features. Advanced driver-assistance systems (ADAS), automated parking, and luxury features were identified as critical for improving user experience and driving adoption. Efforts to meet and exceed safety standards, such as achieving five-star ratings in Bharat NCAP and Global NCAP, were also discussed as essential for building consumer trust.

The panel concluded by touching upon the importance of end-of-life battery management and fostering a circular economy to ensure environmental sustainability and resource recovery. Panellists agreed that the industry's overarching goal remains creating world-class EVs that position India as a global manufacturing hub while meeting domestic mobility needs.

71. Autocar, Press Report, 2024
72. Arthur D Little, Demystifying the future of hydrogen mobility in India, 2023
73. Autocar, Press Report, 2024
74. RMI, India at 2047, 2024
75. Ibid.
76. Autocar Professional, EV sales in India in CY2024 jump 27% to 1.94 million units, 2025
77. IEA, Global EV Outlook, 2023
78. Hindustan Times, News Report, 2022

FROM WORKERS TO ENTREPRENEURS: BUILDING BHARAT'S WORKFORCE FOR CLEAN TECH MANUFACTURING

The panel discussion on **'From Workers to Entrepreneurs: Building Bharat's Workforce for Cleantech Manufacturing'** was held between **Adil Zainulbhai,** Chairman, Capacity Building Commission, Government of India; **Arpit Sharma,** CEO, Skill Council for Green Jobs; **S Sunder Manoharan,** Vice Chancellor, Pandit Deendayal Energy University, Gandhinagar, Gujarat; **Amit Singh,** Chief Executive Officer, Adani Green Energy Ltd, and **Manish Kumar,** Visiting Professor for Economics, Indian School of Business; Former MD and CEO, National Skill Development Corporation (NSDC); and was moderated by **Aakash Sethi,** CEO, QUEST Alliance.

Context and rationale

India faces an immediate shortage of skilled labour to support the cleantech manufacturing sector and to meet its sustainability targets. India's cleantech manufacturing sector is already facing significant workforce challenges; Indian energy firms report difficulty hiring skilled workers, with 72% of employers stating they were experiencing talent shortages.[79] underscoring a significant mismatch between existing workforce capabilities and industry demands. The renewable energy industry in India faces a staggering workforce gap of approximately 1.2 million workers today, with demand projected to rise by 26%,

79. International Energy Agency, 2024, World Energy Employment

Council for International Economic Understanding | bharat CLIMATE FORUM | Dalberg
Bharat Climate Forum 2025

creating a need for 1.7 million skilled professionals by 2027.[80] Meanwhile, countries like China have invested in cleantech manufacturing capabilities for decades, enabling them to dominate the global supply chain and reap substantial benefits. To remain competitive, India must urgently assess the extent of its workforce gaps and implement targeted interventions to bridge them.

India's workforce shortage is a critical limiter of the current and future growth of the cleantech manufacturing workforce. This lack of experienced local staff to manage and operate cleantech manufacturing facilities hampers the development of the domestic sector by deterring the private and international investment needed for the industry. Although India has made strides in upskilling its workforce through various initiatives, such as the Suryamitra Skill Development Program, the Vayumitra Skill Development Program, and the Renewable Energy Skill Development (RESD) Programs by NSDC, clean energy jobs are unlikely to keep flowing unless the skills base is significantly strengthened to meet comprehensive demands. Bridging this gap is essential for India to capture a larger global market share and fulfil its cleantech ambitions.

A key reason limiting India's cleantech manufacturing workforce pipeline is the limited education on it in India. Most mainstream education institutes currently do not provide specialized programs for cleantech manufacturing. Even when skilling programs have been developed through Sector Skill Council-affiliated institutes and private non-affiliated, independent institutes, their impact has been low. Challenges such as the limited number of courses, low uptake, and insufficient industry collaboration exist in these skilling programs, hindering the development of a workforce with specialized skills critical for the future.

For instance, in the wind energy sector, only the National Institute of Wind Energy provides specialized training through the Vayumitra program, which only focuses on operational and maintenance functions and no courses for manufacturing. Similarly, the Suryamitra qualification, i.e., the installation segment, accounted for 90% of the trained and certified candidates in solar job roles. Lastly, the scarcity of trainers, limited exposure to automation techniques, and limited practical experience hinder the industry-readiness of candidates. The Green Sector Skill Council (GSSC) addresses this gap by developing green skills frameworks, certifying trainers, and collaborating with industries and training centres to support India's green economy. Skill Council for Green Jobs (SCGJ) has trained over 515,510 individuals and certified 3,060 trainers in renewable energy, waste management, and sustainable practices. Moreover, the USD 6.9 Bn (INR 60,000 crore) plan for the modernization of 1000 Industrial Training Institutes (ITIs) mentions a focus on green jobs. However, only its successful implementation and a marked enrolment increase will demonstrate whether it can turn the tide on green skill gaps.

Over the coming years, India's cleantech industry – and its skilling needs – will evolve substantially. For example, moving up the value chain from assembling/servicing solar panels to manufacturing them on the assembly line will require a different set of problem-solving and interpersonal skills. Further, the growth of manufacturing in new technologies may place more specialized demands on technical skills. For example, the manufacturing of lithium-ion batteries – expected to grow rapidly as demand for EVs increases – requires more specialized skills to work on electrode manufacturing and cell assembly.

Understanding the workforce demand across cleantech sectors and the expected variations is key to building and sustaining our competitiveness. A detailed demand assessment must account for the diverse needs of cleantech subsectors—each at varying stages of development—and identify targeted interventions to build a future-ready workforce. At present, understanding these different and specialized needs is siloed within individual organizations and industries; as a result, alignment on skilling requirements and curricular norms is not evolving quickly enough.

Workforce demand in each sector can be assessed across manufacturing operations and innovation. These are summarized below and illustrated in Figure 13:

- **'Manufacturing operations'** refers to the workforce that executes tasks essential to producing goods and services, ranging from assembly line operators to more senior and/or managerial roles. The size and capability of this workforce are directly correlated with the output of the sector: the number of units that can be produced, the volume of cleantech

80. Business Standard, 2024, Skills shortage hampers India's clean energy goals and manufacturing plans

Figure 13: Workforce demand in climate-tech manufacturing sectors

projects that can be undertaken in the short- and medium term, and the effectiveness with which those projects can be managed in the long-term.

- **'Innovation'** refers to the research and development workforce that focuses on strengthening the means of production. Continuous innovation in product design and manufacturing processes is important to driving up unit productivity and bringing down production costs—both critical to building global competitiveness. This workforce also stays abreast of global advancements in the cleantech space and would be responsible for integrating these advancements into design, process, and even skilling curricula.

Potential opportunities and challenges

The opportunities for developing a cleantech manufacturing workforce in India are clear:

- Driving indigenization of crucial cleantech supply chains in India by 2030 (and beyond) with a skilled workforce for both manufacturing operations and innovation with an estimated domestic market opportunity of USD 120-150 Bn annually
- Enabling a just transition from traditional energy sectors and absorbing nearly 1,10,000 workers in the fossil fuel sectors by the end of the decade.[81]

There are challenges to addressing these opportunities that must be tackled:

- Technology disruptions in this industry are fast. Existing technology is frequently replaced with more efficient and cost-effective solutions, necessitating frequent reskilling.
- Access to certifications and education in emerging clean energy sectors tend to be less established than in traditional energy industries
- Industry skilling programs in cleantech manufacturing have had limited success, with Bosch, Tata, and Mahindra as the only successful partnerships
- Different cleantech sectors have very different skill requirements, which limits labour mobility across sectors. For instance, every supply chain step in the EV battery chain, from extraction to battery pack production, requires specialized expertise, which limits cross-sector shifts
- Wages in clean energy sectors have been low, even after adjusting for local purchasing power parity,[82] limiting the interest of the workforce in joining the sector
- Timely and successful implementation of announced green skilling plans (e.g., Modernization of ITIs) to ensure quality skilling of the workforce for cleantech manufacturing in India

Key insights from panel discussion

The discussion explored challenges and opportunities in building a cleantech workforce, emphasizing the need to align educational systems, industry requirements, and societal attitudes. Participants highlighted the critical role of vocational education, noting China's success in integrating vocational training into its economic strategy by making it aspirational, in contrast to India's prevailing stigma around vocational courses. This stigma was identified as a barrier to leveraging the economic opportunities offered by cleantech.

A key issue discussed was the disconnect between local demand and supply of skilled workers, with regional disparities and migration often becoming necessary. Interestingly, participants noted gendered patterns in migration, with women showing greater openness to migration but facing workplace barriers, whereas men faced challenges related to self-sufficiency during migration. The need to better prepare vocational training institutes like ITIs was also underscored, including training for instructors, and better alignment with industry needs.

Government initiatives and civil services were discussed as pivotal in creating a future-ready workforce, with examples like the Capacity Building Commission's courses on emerging technologies for civil servants.[83] These initiatives aim to build awareness of technologies like cleantech, artificial intelligence, and energy transitions among civil servants and have been utilized across the hierarchy. Panellists also noted that while the government played an important role in developing human resources, over-reliance on government schemes could limit outcomes, and advocated for demand-driven training models supported by greater private sector collaboration.

Industry partnerships emerged as a critical factor, with participants emphasizing that the responsibility for workforce readiness should be shared between training institutions and industry. Examples of successful models included private sector investments in training centres, such as Tata Power Skill Development Institute's Green Hydrogen Lab[84] and ReNew's initiatives for skilling salt pan workers in Gujarat.[85] These partnerships not only enhanced training infrastructure but also supported local employment and skill development. However, the high costs associated with advanced cleantech training, such as hydrogen-related technologies, remain a challenge, necessitating increased industry involvement and government support.

The session also addressed the need for enhanced collaboration between academia and industry. Participants shared innovative approaches such as academia adopting entrepreneurial models to combine training with on-the-job manufacturing experiences. This approach not only ensures practical experience in ultra-skilled and specialised roles but also generates sustainable revenue for institutions. The importance of inculcating safety habits was noted, with panellists emphasizing its inclusion from the initial training stages itself.

Panellists also noted that more efforts needed to be made to spread awareness about courses and programmes for highly skilled and specialized roles such as crane operators. They observed that such roles commanded competitive salaries and could help counter the perception that vocational education was only for low-paying or semi-skilled roles.

The role of technology in scaling training efforts was another key area of focus. Emerging tools, such as AI-powered training modules, were suggested as solutions to alleviate the shortage of skilled trainers and enhance the accessibility of technical knowledge.

Finally, panellists emphasized the need for a holistic ecosystem approach to address these interconnected challenges. The session concluded with a call for greater collaboration, innovative solutions, and a deeper understanding of the problems to drive sustainable progress in clean-tech workforce development.

81. International Energy Agency, 2024, World Energy Employment

82. International Energy Agency, 2024, World Energy Employment
83. Capacity Building Commission, Launch of Phygital Course "Emerging Technologies"
84. Tata Power Skill Development Institute, Training Facilities
85. MNRE, Renew Power: Women for Climate

HIGH-LEVEL FIRESIDE CHAT

BHARAT MANUFACTURING MODEL WIN-WIN FOR THE WORLD

The high-level fireside chat on **'Bharat manufacturing model: Win-win for the world'** was held between **Ashok Kantha,** Former Indian Ambassador to China; **Shyam Saran,** Former Foreign Secretary, Govt of India; and **Shaurya Doval,** Director, India Foundation and MD, Torch Investment Management; and was moderated by **Gaurav Gupta,** Global Managing Partner, Dalberg Advisors.

The chat focused on India's potential to become a global cleantech manufacturing hub by leveraging its geopolitical positioning, fostering private sector innovation, and investing in R&D. It emphasized balancing scalability with quality, aligning government policies with industry needs, and building strategic international collaborations to compete effectively on the global stage.

Context for the fireside chat

The fireside chat explored the pivotal question: can India emerge as a global manufacturing hub with a focus on cleantech and renewable energy, while balancing domestic needs and global expectations? The discussion sought to offer a reality check, moving beyond aspirations to analyse the geopolitical, economic, and strategic factors shaping this ambition. With global shifts favouring diversification away from China, rising climate consciousness, and India's significant domestic energy transition needs, the speakers delved into India's competitive advantages and the foundational elements required for success. The conversation emphasized understanding geopolitical positioning, fostering innovation, ensuring long-term stability for investors, and maintaining quality as India scales its cleantech manufacturing ambitions.

Insights from the fireside chat

India's geopolitical positioning offers a unique advantage as the world seeks alternatives to China's dominance in cleantech manufacturing. The speakers believed that India is seen as a credible counterweight to China, which creates opportunities for collaboration with countries in Global North and Global South. However, they cautioned that these advantages must be leveraged strategically. This includes gaining access to high technology – such as semiconductors – where countries are willing to share expertise with India. To capitalize on this advantage, India needs a coherent long-term developmental strategy that aligns its geopolitical leverage with its domestic manufacturing goals.

The speakers attributed China's meteoric rise in cleantech manufacturing to strategic investments in R&D, industrial policy, and scaling. They pointed out that China's emphasis on self-reliance, robust factory floor management, and long-term policy commitments allowed it to dominate sectors like solar panels, electric vehicles, and lithium-ion batteries. In contrast, India's investment in R&D is at 0.6% of GDP, far below global competitors.[86] The challenges faced in developing a unified regulatory framework and effectively integrating SMEs into strategic supply chains, further add to the complexity of addressing India's current hurdles. While India should learn from China's successes, speakers cautioned against replicating unsustainable models that compromise economic viability.

The speakers highlighted achieving a balance between innovation, scalability, and quality as a critical challenge for India's cleantech ambitions. They underscored the importance of fostering private sector innovation and scaling up Indian entrepreneurs to compete globally. They advocated for a market-driven approach where the private sector is supported through favourable policies, low-cost capital, and ease of doing business. However, they emphasized that quality must remain a priority, especially as India ramps up domestic consumption of renewable energy technologies. A failure to address quality while chasing scale could undermine the global credibility of Brand India. The speakers stressed that enabling the private sector to lead this transformation is key to achieving both scale and world-class standards.

The discussion emphasized that innovation must drive India's cleantech manufacturing trajectory. This includes developing unique products and processes that align with India's competitive strengths rather than merely replicating existing global manufacturing practices. Additionally, collaboration with global partners to diversify supply chains and reduce dependency on any single country is crucial. Speakers called for targeted investments in R&D, human resource development, and strategic partnerships to create a resilient ecosystem that supports India's ambitions as a global manufacturing leader.

The discussion concluded with a clear consensus that India's path to becoming a global cleantech manufacturing hub requires a strategic, multi-faceted approach. Leveraging its geopolitical position, fostering private sector innovation, and investing in long-term R&D were identified as critical imperatives. Speakers highlighted the need for a coherent developmental strategy that prioritizes quality alongside scalability, enabling India to compete effectively on the global stage. By aligning government policies, private sector capabilities, and international collaborations, India can not only meet its domestic renewable energy needs but also establish itself as a world-class manufacturing leader in cleantech.

86.Ministry of Education, Expenditure on Research and Development, 2023

GLOBAL PARTNERSHIPS FOR GREEN AMBITIONS: TECHNOLOGY, TRADE, AND RESOURCES

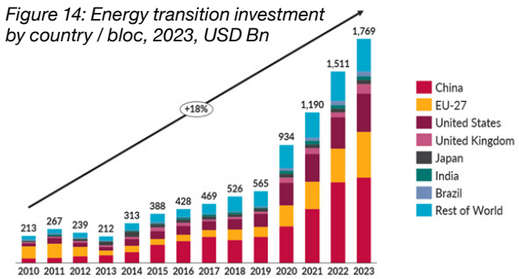
The panel discussion on **'Global Partnerships for Green Ambitions: Technology, Trade, and Resources'** was held between **Taranjit Sandhu**, Former Indian Ambassador to the USA; **Lekhan Thakkar,** Joint Secretary, National Security Council, India; and **Lord Adair Turner,** Chair, Energy Transitions Commission; and was moderated by **Sachin Chaturvedi,** DG, RIS.

Meenakshi Lekhi, Former Minister of State for External Affairs and Culture presided over the panel.

Context and rationale

Global energy transition investments reached USD 1.8 Tn in 2023, up 17% from the previous year.[87] Additionally, global manufacturing investments in five key clean technology supply chains—solar PV, Wind, EVs (including batteries), Electrolysers, and Heat pumps—jumped 50% to USD 235 Bn in 2023, up from USD 160 Bn in 2022. Solar PV and batteries led the investments, which together accounted for 80% of the total investments in 2023.

Figure 14: Energy transition investment by country / bloc, 2023, USD Bn



India was among the top 10 destinations for investment in the energy transition in 2023, receiving investments of USD 31 Bn, but still far short of the USD 120-140 Bn in investment needed each year to meet net-zero targets by 2050.[88] Among key sectors receiving investment in 2023, mobility and transport (including EV, Battery Energy and Storage Systems and other green mobility infrastructure) topped the list, followed by energy (renewable energy, including solar and wind).[89]

87. BNEF, Energy Transition Investment Trends 2024
88. BNEF, Energy Transition Investment Trends, 2024
89. FSG, India's Green Revolution 2.0, 2024

India is forging strategic international partnerships to drive innovation and investment in cleantech and energy transition, solidifying its position as a key player in the global space. India has partnerships with the USA, the European Union, Saudi Arabia, Brazil, Denmark, and QUAD member states focused on green hydrogen, supply chains, biofuels and energy storage.[90] Most technology-sharing partnerships focus on sharing the latest technological advancements with India to fuel cleantech R&D and innovation and design capabilities; knowledge sharing to support optimization and cost reduction for indigenization; technical mentorship for start-ups; and co-investment models to scale up production of emerging technologies.

Bilateral partnerships play a significant role in India's energy transition and cleantech ambitions. Major bilateral partnerships include the US-India Strategic Clean Energy Partnership (USISCEP), India-EU Clean Energy and Climate Partnership (CECP) and Partnership with the German agency Gesellschaft für Internationale Zusammenarbeit (GIZ). Through USISCEP, the US and India are expanding collaboration to strengthen global clean energy supply chains, working together to unlock USD 1 Bn in multilateral finance through the IBRD to support the clean energy transition.[91] The India-EU CECP partnership is in the third phase (2025-2028). It focuses on deeper cooperation in five priority areas: i) green hydrogen, ii) offshore wind, iii) regional connectivity, electricity market integration and smart grids, iv) energy efficiency and v) energy and climate diplomacy. GIZ partners with India on renewable energy, energy efficiency, and sustainable urban development projects, including the Indo-German Energy Programme (IGEN), Smart Cities Mission, and Green Cooling Initiative (GCI).

India has a strong presence in global collaborations and alliances dedicated to climate action and energy transition. Notable initiatives include the Renewable Energy Collaboration, the International Solar Alliance (ISA), Cleantech Collaborations, and the Global Biofuel Alliance (GBA). ISA aims to unlock USD 1 Tn in solar investments by 2030 through its 'Towards 1000' strategy, focusing on reducing both technology and financing costs.[92] The GBA aims to promote the development and adoption of sustainable biofuels and set relevant standards and certification. India is a key member, collaborating with countries like Brazil and the USA to advance biofuel technologies. Australia and India collaborate under the Renewable Energy Collaboration, focusing on investments in renewable energy and developing a skilled renewable workforce through targeted training and capacity-building initiatives.

India has also established strong partnerships with the Global South to advance cleantech through knowledge and technology sharing, technology transfer, capacity building, and joint R&D initiatives to accelerate energy transition in partner countries. Bilateral trade partnerships with countries such as Bhutan, Nepal, Sri Lanka, and Tanzania, among others, focus on cleantech and clean energy collaboration. For Bhutan and Nepal, India supports hydroelectric capacity expansion to 25 GW by 2040 and 28 GW within the next 10–12 years, respectively, with Indian investment and access to the Indian energy market. In Sri Lanka, India funded 2.2 MW hybrid renewable energy systems through a USD 11 Mn grant in the Palk Bay islands. In Tanzania, a Triangular Development Partnership launched in July 2024 by the United States, India, and Tanzania focuses on building a stronger grid, improving regulatory frameworks, and developing utility-scale solar projects.[93] These initiatives reflect India's active role in fostering sustainable energy transitions and regional partnerships across the Global South.

Global partnerships could ensure raw material availability for India's cleantech manufacturing. Raw material availability is a key vulnerability for India's cleantech manufacturing ambitions. Critical minerals such as lithium, cobalt and nickel have a 100% dependency on imports, with no domestic production expected for at least a decade. There are also high single-country exposure risks; for example, Belgium has supplied India with roughly 50% of Copper Oxide and 65% of Nickel Sulphate over the last 5 years, Japan approximately 80% of Copper Cathodes, and China approximately 80% of synthetic and 65% of natural graphite respectively. However, the nature of global supply chains presents opportunities. For example, while China refines 90% of the global graphite for EV battery anodes, the primary producers are Madagascar, Mozambique and Brazil, with Tanzania having one of the largest reserves. While India already imports significant quantities from Madagascar and Mozambique, stronger trade partnerships can be explored with raw material producers to reduce dependencies on potential competitors.[94] Hence, it is crucial for India to establish robust bilateral trade partnerships with key raw material-supplying countries, particularly for materials with limited or non-existent Indigenous supplies, to

90. Summarised from PIB notes and releases
91. US Embassy in India, Roadmap For U.S.-India Initiative to Build Safe and Secure Global Clean Energy Supply Chains
92. PIB, ISA hosts 7th session of its Annual Assembly, 2024
93. USAID, U.S., India, and Tanzania Partner to Accelerate Renewable Energy Development in Tanzania, 2024
94. IEEFA, India's Hunt for Critical Minerals, 2024

safeguard its cleantech manufacturing aspirations.

Cleantech manufacturing growth depends on strengthening global partnerships in technology, investments, and trade. Developing export networks for cleantech components, clean energy, and fuels will help establish India as a global manufacturing hub. Additionally, India can significantly support the Global South with cleantech advancements and energy transition.

Potential opportunities and challenges

Global partnerships offer India significant opportunities to accelerate its cleantech manufacturing capabilities, improve its international standing in renewable energy production, and achieve its sustainability targets.

- **Accelerated technology exchange** by leveraging partnerships with technologically advanced nations for cutting-edge cleantech solutions. Key focus areas include battery cell and pack technology, efficient solar modules and PV cells, EV motor and powertrain designs, fuel cells, hydrogen combustion engines, and high-efficiency electrolyzers for hydrogen production.
- **Investment acceleration**: India's partnerships with countries like the United States, Germany, and Japan can potentially attract substantial foreign investments into its cleantech sector. Mechanisms such as public-private partnerships (PPPs), green bonds, and concessional loans can further unlock funding to meet the requirement for renewable energy targets by 2030.
- **Export growth:** By enhancing its cleantech manufacturing capabilities, India can position itself as a global hub for affordable climate technologies and leverage the 'India Plus Many' strategy as a strategic supplier of cleantech components for Western countries and the Global South.
- **Shaping cleantech advancement in the Global South**: India can play a pivotal role in bridging the technology gap for developing countries in the Global South. Partnerships focused on knowledge sharing, affordable solutions, and technology transfer can enable these nations to adopt clean energy technologies, driving global sustainability goals.

However, realizing the full potential of these partnerships comes with its share of challenges.

- **Lower bargaining power**, particularly for raw material partnerships, considering global demand-supply gap
- **Inadequate technical capabilities for adopting advanced cleantech often result** from gaps in technical expertise, infrastructure, and access to advanced technologies.
- **Global macro-economic trends and local implementation-related issues are** impacting global investments in India

Addressing these challenges requires targeted interventions to streamline regulations, foster private-public collaboration and build technical and institutional capacities for sustainable industrial transformation.

Keynote address

Mrs. Meenakshi Lekhi delivered an impactful keynote address exploring the critical role of global partnerships in India's green ambitions, emphasizing the necessity for collaboration in technology, trade, and resource management. Against the backdrop of India's strategic goals – achieving net zero by 2070, becoming a

developed nation by 2047, and sourcing 50% of energy needs from non-fossil sources by 2030 – she outlined the challenges and opportunities in achieving these ambitions. Her speech provided a roadmap for harnessing India's strengths while addressing its structural gaps and advocating for diplomacy that is firm, strategic, and value driven.

Mrs. Lekhi highlighted India's unparalleled position as a bridge between the Global North and South, blending the economic capabilities of developed nations with the developmental challenges of emerging economies. India's diverse identity—a civilizational power with democratic institutions and a large, aspiring middle class—positions it as a credible advocate for global equity in green transition. She emphasized that India's leadership must leverage its moral authority and democratic values to lead initiatives like the International Solar Alliance, Global Biofuels Alliance, and disaster-resilient infrastructure programs.

Recognizing the importance of targeted partnerships, Mrs. Lekhi underscored the need for India to identify collaborators who can provide essential technologies and access to critical minerals. She stressed that global partnerships must be approached with precision, aligning India's technological needs with its resource deficits. Furthermore, she noted that India should strategically focus on filling global market gaps by investing in technologies and devices such as transformers, chargers, and wafer-based systems for solar and semiconductor industries.

Mrs. Lekhi addressed the dual challenges of financing and communication. While India's economic resilience makes it an attractive destination, she called for more effective communication of India's achievements in renewable energy and sustainability. Highlighting the global dominance of countries like China in green technologies, she advocated for disruptive innovation and financial incentives to attract global capital.

Her speech emphasized that global diplomacy must translate into actionable outcomes at the local level. Mrs. Lekhi called for stronger alignment between global policies and local governance structures, particularly in areas like waste management, smart grids, and decentralized resource utilization. She cited the importance of municipal and state-level bodies in implementing sustainable solutions, advocating for policies that minimize energy waste and maximize resource recyclability.

Mrs. Meenakshi Lekhi's keynote address urged India to

harness its unique strengths to lead the global green transition. By combining strategic diplomacy, targeted partnerships, and strong local governance, India can achieve its ambitious energy and sustainability goals while setting an example for the world. Her emphasis on narrative building, resource utilization, and actionable diplomacy serves as a roadmap for aligning global ambitions with domestic priorities, ensuring India's leadership in shaping a sustainable future.

Key insights from panel discussion

Panellists discussed a wide spectrum of issues surrounding the green energy transition and its implications for India's global partnerships, particularly with the United States and Europe. Key areas included the identification of critical technologies and resources necessary for energy transition, such as rare earth minerals and advanced materials, alongside the role of strategic partnerships in addressing these gaps. Discussions also emphasized the importance of integrating energy security with food security, ensuring that progress in one domain does not compromise the other. The recently announced Green Steel Mission and initiatives like National Green Hydrogen Mission and Bharat Small Reactors were highlighted as pivotal developments in India's energy landscape.

Energy diplomacy and financing were highlighted, with panellists stressing the need for international collaboration, in areas such as renewable energy, clean technology, and smart grids. The US-India Clean Energy Finance Task Force and Climate and Clean Energy Agenda 2030 Partnership were cited as instrumental frameworks, with the role of financing mechanisms like the US International Development Finance Corporation (DFC) highlighted in advancing these goals.[95]

A critical focus was placed on addressing challenges related to the global supply chain and technological dependence, particularly in the context of rare earth processing and clean energy manufacturing. Efforts to address these, such as international partnerships under initiatives like the Mineral Security Partnership (MSP) and advanced material research, were highlighted. The importance of collaboration with Quad countries and leveraging platforms like the National Critical Minerals Mission was emphasized to strengthen India's clean energy ecosystem. Panellists highlighted the need for India to develop a robust domestic ecosystem to reduce reliance on imports. Scale and targeted investments were identified as key strategies to build competitive manufacturing capabilities in solar PV, EVs, and batteries.

The discussion also explored the implications of geopolitical dynamics, including concerns about protectionism, which pose both challenges and opportunities for India's energy transition. Panellists highlighted the potential for India to leverage partnerships with the Global North to overcome these hurdles while advocating for judicious use of tariffs and incentives to protect domestic industries without stifling innovation and competitiveness.

Panellists also brought attention to the urgency of addressing global emissions, noting that while technological advancements in renewable energy and battery storage have significantly reduced their costs, climate change remains a critical challenge. The role of China's large-scale ecosystem in driving down costs was acknowledged, and panellists discussed the need for India and Europe to develop similar scale-driven ecosystems.

Finally, the panellists underscored the importance of leveraging foreign direct investment (FDI) for skill and technology transfer, drawing lessons from China's success in this area. Suggestions included fostering joint ventures and local content requirements to maximize the benefits of such investments. The session concluded with a call for integrating food and energy security strategies, carbon reduction, and inclusive development into future policy frameworks.

95.These discussions were held prior to changes announced by the Trump administration to the IRA and US participation in the Paris Agreement and any impact on these partnerships is currently not incorporated

FIRESIDE CHAT

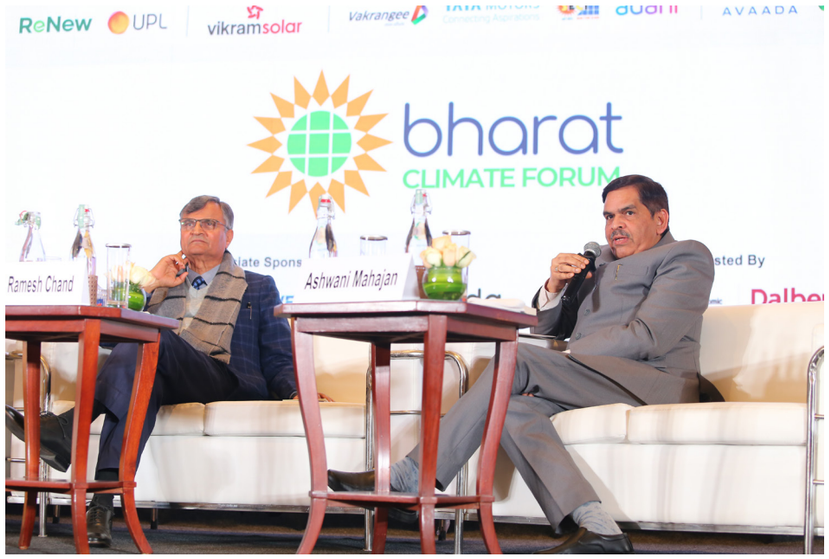
HOW TO MAKE RURAL INDIA CLIMATE READY?

The fireside chat on **'How to make rural India climate-ready?'** was held between **Prof. Ramesh Chand,** Member, NITI Aayog; **Ashwani Mahajan,** National Co-Convener, Swadeshi Jagaran Manch; and Vikram Shroff, Vice-Chairman and Co-CEO, UPL Group; and was moderated by **Komal Shah Bhukhanwala,** Director, SML Group.

The chat focused on making rural India climate-ready by addressing agriculture's role in emissions and climate resilience through policy reforms, financial incentives, and technological innovations. It emphasized sustainable practices, protecting traditional systems, and aligning regulatory frameworks with climate targets to empower rural communities and mitigate climate change impacts.

Context for the fireside chat

The fireside chat addressed the critical intersections of climate change, agriculture, and rural development. With up to 65% of India's population dependent on agriculture, the speakers emphasized the urgency of addressing the sector's vulnerabilities to climate change. Key topics included the role of innovative ag-tech and clean-tech solutions, the disproportionate contribution of agriculture to greenhouse gas emissions, and the pressing need for regulatory and financial frameworks that support sustainable practices. The speakers explored the dual challenge of improving agricultural productivity while reducing emissions, particularly nitrous oxide – a potent greenhouse gas with long-lasting effects. They also examined how financial incentives could enable farmers to adopt advanced, climate-resilient solutions that ensure soil health, water conservation, and nutritional security.



Insights from the fireside chat

The speakers emphasized agriculture's dual role as a contributor to and a potential mitigator of climate change. They highlighted that agriculture contributes significantly to India's emissions, particularly through methane from paddy cultivation and livestock, and nitrous oxide from nitrogen-based fertilizers. However, solutions exist. Practices such as direct seeding of rice and reduced reliance on standing water can substantially lower methane emissions from rice. They underscored the need for policy reform, such as revising subsidies like free power for irrigation. On the technological front, advancements in crop varieties, like those designed for direct seeding or nitrogen fixation, present a promising pathway to reduce emissions while enhancing productivity.

The discussion showcased several climate-smart agricultural innovations, including efforts in seed breeding for crops resilient to extreme weather and the introduction of water-efficient alternatives like sweet sorghum. Additionally, the development of soil health solutions, such as microbial enhancers and products preventing fertilizer leaching, was presented as essential for building farmer resilience. The speakers also noted technological interventions like animal feed additives to reduce methane emissions from cattle, reflecting the industry's focus on reducing the environmental impact of farming practices.

The speakers addressed the critical role of financial frameworks in facilitating the adoption of climate-resilient practices. They pointed out that empowering farmers through financial incentives for adopting advanced solutions, such as solar-powered cold storage and sustainable farming methods, is imperative. Regulatory reform is also necessary, with current frameworks lagging behind the innovation in fertilizers and farming technologies. The speakers stressed the importance of aligning policies with climate targets to enable meaningful change and support for farmers.

The fireside chat underscored that making rural India climate-ready requires a multi-pronged strategy integrating policy reform, technological innovation, and financial incentives. Agriculture, while a significant contributor to emissions, also offers opportunities for mitigation through sustainable practices and advanced technologies. The speakers highlighted the critical need to align regulatory frameworks with climate targets and to incentivize farmers to adopt climate-resilient solutions. By fostering collaboration between policymakers, industry leaders, and rural communities, India can transform its rural landscape into a model of climate resilience and sustainable growth.

FINANCING AN ATMANIRBHAR BHARAT: UNLOCKING CAPITAL FOR CLEAN TECH MANUFACTURING

The Panel Discussion on **'Financing an Atmanirbhar Bharat: Unlocking Capital for Cleantech Manufacturing'** was held between **Nivruti Rai,** CEO, Invest India; **Annika Seiler,** Lead – Clean Energy Supply Chains, ADB; **Auguste Tano Kouamé,** Country Director for India, World Bank; and **Rajnish Kumar,** Former Chairperson, SBI; and was moderated by **Shalabh Tandon,** Regional Head of Operations & Climate Change, IFC South Asia.
Jayant Sinha, Former Minister of State, Finance, presided over the Panel Discussion.

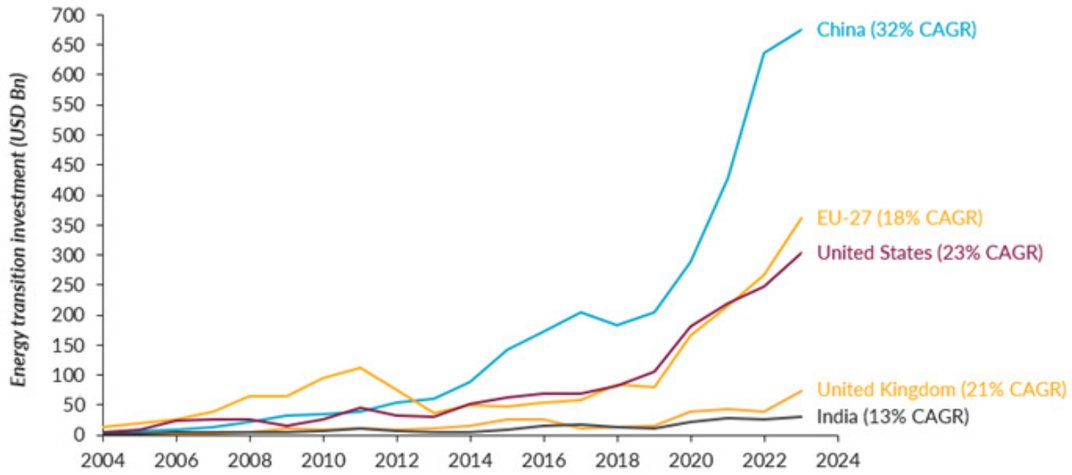
Context and rationale

Globally, many high-emission countries are leading the net-zero transition, investing 3-5% of their GDP in climate-tech and cleantech manufacturing. A significant portion of these investments – approximately 60% – comes from debt instruments such as green bonds. At the same time, the remainder is driven by equity financing from the private sector, including venture capital and private equity.[96] This has been catalyzed in countries such as the US, the EU, and the UK through strong policies and investment standards such as the Inflation Reduction Act (IRA),[97] the Green Deal, Energy Transition Financing, and ESG Regulations. China combines favourable policies with extensive subsidies, creating a cost-competitive environment that attracts substantial green investments and solidifies its position as a leader in cleantech manufacturing.

India is currently investing just 1.5% of its GDP in climate-tech. In 2023, China's energy transition investments were 22 times greater, while the EU and US invested 10 times more than India (refer to Figure 15). Although India's investment has grown steadily at 13% CAGR since 2004, a significant gap remains in meeting the financing demand for its net-zero transition. While there is a strong push to scale domestic capacities across cleantech sectors, these expansions must be financed at competitive rates to ensure cost-effectiveness in India. For instance, India's installed solar capacity is projected to increase from 67 GW to 280 GW by 2030,[98] but the cost of manufacturing solar cells domestically is still 1.5–2 times higher than Chinese imports,[99] making it challenging for domestic players to compete on price. Overall, India needs an annual

96.IMF, Emerging Economies Need Much More Private Financing for Climate Transition, 2023
97.The Trump Administration has issued an Executive Order to repeal the IRA
98.PIB, India is marching ahead in the Renewable Energy Sector, 2023
99.PV Magazine, Indian solar cells costs more than Chinese imports, says CRISIL, 2024

Figure 15: Energy transition investment trend for high-emission countries between 2004-2023



investment of USD 120-140 Bn across all sectors, increasing to a cumulative USD 7.2-12.1 Tn by 2050, to achieve net-zero ambitions across all industries. Financing from domestic and international sources is crucial, with the Reserve Bank of India suggesting green finance should account for at least 2.5%—3.5% of GDP annually until 2030.

Figure 15: Energy transition investment trend for high-emission countries between 2004-2023[100]

Cleantech investments in India are primarily driven by domestic debt and foreign equity, with most funding concentrated in renewable energy (RE) and e-mobility (EV). Nascent sectors struggle to receive financing. Given the government's push towards RE and EV via policies such as PLIs and FAME, 70-80% of funding for these sectors today comes from debt, most of which is from domestic banks, while the remaining equity investments from global PE funds and VCs drive 20-30%. In contrast, R&D-heavy, nascent cleantech sectors such as green hydrogen and bioenergy with varying levels of policy interventions still receive limited financing. Given the risk-averse nature of debt financing, most funding for these sectors is driven by equity investments, most of which come from foreign investors. However, this reliance on foreign capital underscores the need for a stronger push toward domestic equity investments in emerging technologies to drive innovation. At the same time, debt funding needs to become more accessible and cost-effective to attract foreign capital, thereby lowering the overall cost of financing for these nascent sectors.

Despite growing investments, cleantech financing in India faces several systemic and sector-specific challenges. A significant hurdle is a risk-return mismatch for equity investors, where rates of return on climate-tech investments are either lower or take longer to realize than other startups such as D2C, tech, and AI, discouraging financiers. Debt lending is also limited, as banks and NBFCs prefer short-term, low-risk projects over manufacturing-focused ventures requiring high upfront costs and extended payback periods. Additionally, India's capital cost is significantly higher, with borrowing rates ranging from 8–20%, compared to 2–5% in developed economies, making domestic projects less competitive globally. Lower equity participation further constrains early- and growth-stage cleantech companies, as equity markets have been slow to embrace these ventures due to their uncertain profit margins. Moreover, policy and regulatory gaps, especially in nascent cleantech sectors (e.g., green hydrogen, bioenergy), exacerbate these challenges with the absence of cohesive green financing policies, tax incentives, or long-tenor green bonds limiting the flow of affordable capital. This also affects startups that offer promising innovations, often in nascent sectors, but face funding challenges to scale up. Lastly, the financial sector's absence of comprehensive ESG investing guidelines further exacerbates these challenges. Unlike developed economies where financial institutions are incentivized or mandated to allocate capital to sustainable projects, India lacks clear frameworks for ESG-linked investments.

Addressing these challenges is essential to scaling domestic cleantech manufacturing and reducing India's reliance on imported components. India can attract significant domestic PE participation by improving access to affordable capital, incentivizing domestic investors, and developing robust regulatory frameworks. Moreover, strengthening debt-equity ratios, creating specialized financial instruments like green bonds, and fostering blended finance mechanisms can help mitigate risks and unlock long-term domestic and foreign capital for cleantech manufacturing.

Potential opportunities and challenges

The opportunities for unlocking capital to boost cleantech manufacturing in India and align with India's Atmanirbhar mission are clear in terms of:

- Significant domestic market potential of USD 120-150 Bn annually by 2030 from renewable energy and e-mobility
- Potential export opportunity of USD 40-45 Bn annually by 2030, assuming 10% global export share
- Potential to close the USD 260-270 Bn energy transition financing gap by 2030

The challenges in addressing these opportunities are as follows:[101]

- **High cost of financing for new projects,** particularly for emerging technologies like green hydrogen, offshore wind, and battery storage – due to policy uncertainty, technology risks, and offtake risks
- **Low-risk appetite among financiers:** Financing is readily available for established technologies, but emerging ones struggle to attract funds.
- **Limited long-term financing instruments:** Domestic capital markets lack sufficient long-duration investment options like long-term AAA-rated bonds with no issuances beyond ten years. This limits the ability to attract patient capital needed to fund large-scale manufacturing investments.
- **Underutilized ESG financing sources such as green bonds:** The global green financing market reached USD 1.5 Tn in issuances in 2022, but Indian entities only issued USD 8.8 Bn during the same period. While sustainability-linked or green bonds and loans are rising, more substantial disclosure standards and credible ESG-linked financing strategies backed by regulation are needed to support growth.
- **Fragmented MDB funding:** Multilateral Development Banks have yet to play a material role in scaling financing. Their current approach is often disaggregated, focusing on smaller pilot investments. Domestic DFIs need to aggregate smaller opportunities into larger investable pipelines to attract MDB capital
- **Lack of robust subsidies in nascent cleantech sectors:** Without direct financial support or robust carbon markets, profitability in these sectors is challenging; hence, additional incentives are needed to encourage domestic manufacturers
- **Lack of robust climate-risks-related investment regulations for financial investors: Unlike developed economies, where investors are incentivized or mandated to allocate a certain percentage of their portfolios to sustainable projects, Indian institutions operate without clear guidelines, although SEBI and RBI have** issued initial direction on climate risks disclosures.

Overall country-level risks: Additionally, developing countries face higher sovereign risks, foreign currency risks, and payment risks that raise their capital costs.

Keynote address

Shri Jayant Sinha, a prominent Indian leader and former Minister of State for Finance, introduced India's first net-zero legislation in 2021, showcasing his commitment to climate action. Currently, as Chairperson of the Standing Committee on Finance, he champions green growth and sustainable development.

Shri Jayant Sinha's keynote address focused on the critical financial architecture needed to drive India's green ambitions. Speaking ahead of the panel discussion on financing an Atmanirbhar Bharat, Sinha emphasized the importance of unlocking USD 50–100 Bn incremental investment annually to achieve net zero by 2070,[102] meet renewable energy targets by 2030, and position India as a green economic powerhouse. This is on top of the USD 68 Bn invested in 2023,[103] as to meet its renewable energy targets, India needs an annual requirement of USD 120–140 Bn across all sectors.[104] He noted that this figure represents a doubling of current capital expenditures,[105] demanding significant

100.Economist Impact, Scaling clean energy: financing and transition strategies for India's sustainable future, 2024; McKinsey Decarbonizing India report, 2022

101.Economist Impact, Scaling clean energy: financing and transition strategies for India's sustainable future, 2024
102. Reuters, India needs to invest up to $100 bln/yr more to achieve 2070 net zero goal, 2023
103. IEA, India – World Energy Investment 2024 – Analysis, 2024
104.Economist Impact, Scaling clean energy: financing and transition strategies for India's sustainable future, 2024
105.Reuters, India needs to invest up to $100 bln/yr more to achieve 2070 net zero goal, 2023

effort to mobilize such funds. His speech outlined the policy interventions and innovative financial instruments required to mobilize capital and drive a sustainable economic transformation.

Shri Jayant Sinha highlighted that India's commitment to net zero is not externally imposed but deeply rooted in national interest. He outlined three key reasons for India's green transition: energy security through domestic renewables, public health improvements by reducing fossil fuel reliance, and climate resilience to counter the adverse impacts of climate change. Framing net zero as 'net positive' for India, he asserted that achieving this goal would drive broader economic growth, underscoring that these investments will yield high returns in terms of energy security, job creation, and public health benefits.

The speech also introduced blended finance as the cornerstone of India's strategy to unlock the required capital. This approach combines concessional capital from governments, multilateral development banks, and philanthropy with commercial, return-seeking capital. He detailed various instruments to facilitate this blend, including credit guarantees, first-loss equity funds, long-term currency hedging mechanisms, and climate insurance solutions. These tools, he emphasized, are essential to de-risk investments and attract private sector participation on a large scale.

The former minister underscored the necessity of clear and targeted policy interventions to enable capital flow. He pointed out that markets alone are insufficient to meet the investment requirements, emphasizing the role of governments and institutions in creating a conducive environment. This includes scaling up blended finance instruments, incentivizing green investments, and aligning national financial frameworks with global green finance practices.

Shri Jayant Sinha's address underscored the transformative potential of India's green transition, framing it as a pathway to economic growth, job creation, and energy independence. However, he emphasized that realizing this vision demands concerted efforts to mobilize capital through blended finance and robust policy frameworks. By leveraging innovative financial instruments and aligning national priorities with global best practices, India can position itself as a leader in cleantech manufacturing and sustainable development, paving the way for a greener, more prosperous future.

Special address

Ms. Nivruti Rai, CEO of Invest India, delivered an engaging special address during the financing panel at the Bharat Climate Forum. Her presentation focused on India's strategies to attract domestic and international capital for renewable energy and cleantech manufacturing, emphasizing the critical role of foreign direct investment (FDI), equity risk capital, and technology transfer in achieving India's ambitious energy transition goals.

Ms. Rai began her address by outlining the significant progress that India has made in areas such as renewable energy research, and highlighted India's target to double its non-fossil energy installed capacity from over 200 GW to 500 GW by 2030 achieving a 50% share of non-fossil sources in total installed capacity. She emphasized that energy growth is directly tied to GDP growth, making this transition crucial to sustaining economic development. She highlighted that despite significant progress, India has attracted only 2% of the global USD 2 Tn renewable energy investment, highlighting the need for greater international financial support, especially from countries with higher historical emissions.[106]

She noted that Invest India is proactively targeting specific sectors, companies, and countries to secure partnerships and reduce dependence on

106.BloombergNEF, Energy Transition Investment Trends 2024

imports, especially from China, which currently supplies a majority of India's solar and EV components.[107,108] She emphasised that a green technology transition was the only way for India to balance its need for rapid economic growth with its climate obligations. Ms. Rai also underscored the urgency of technology transfers to help build India's cleantech manufacturing capabilities, and the need for collaborative efforts to address emissions in hard-to-abate sectors.

Ms. Rai highlighted the evolving economic priorities of modern India, from '*Roti, Kapda, Makan*' to 'Technology, Power, Infrastructure.' She mentioned that, through initiatives to attract FDI and foster global collaborations, Invest India is creating a robust ecosystem to accelerate India's clean energy transition and build resilience in energy infrastructure.

Having framed India's clean energy journey as both a national priority and a shared global responsibility, she concluded by calling upon the audience to collaborate on driving investment and accelerating India's growth in renewable energy.

Key insights from panel discussion

Participants in the panel discussion explored the role of blended finance, concessional funding, and de-risking mechanisms, while sharing diverse perspectives on scaling investments in clean technology manufacturing and infrastructure financing, with a focus on India's policy environment and market dynamics.

A key area discussed was the evolving landscape of blended finance. It was noted that while the concept holds promise, its current scale and impact may be insufficient to drive significant change. Participants outlined efforts to scale climate finance with a 360-degree approach, addressing value chain challenges, energy security, and critical mineral strategies. Emphasis was placed on integrating policy support, capacity development, and public-private partnerships to maximize impact. An example shared included MDB collaborations with the Central Government to develop policy-based loans for boosting clean energy technology manufacturing.

Participants highlighted the domestic banking sector's potential in financing cleantech manufacturing growth. While public sector banks have successfully mobilized funding for renewable energy projects, and the domestic banking system has the capacity to meet further requirements, concerns were raised about high borrowing costs and risk. The need for improved project de-risking though measures such as the government's Letter of Credit (LC) mechanism, and the importance of addressing asset-liability mismatches and measures such as take-out financing were emphasized.

The role of multilateral development banks (MDBs) was another key focus. Panellists discussed recent reforms to MDBs aimed at increasing lending capacity and reducing costs for member countries like India.[109] Examples included leveraging policy reforms to mobilize private sector investments in green hydrogen and solar energy projects, achieving significant multiplier effects in private financing. The potential of Guarantees platforms to de-risk private investments in green technology was also underscored, blending expertise and financing capacities across MDB entities.

The discussion closed with participants touching on efforts at creating new asset classes and aggregating portfolios to address financing gaps, underscoring the urgency of actionable reforms and private sector engagement in green energy investments. Throughout the session, participants acknowledged the critical need for collaboration among public and private stakeholders, coherent policy frameworks, and innovative financial instruments to achieve sustainable development goals.

107.Policy Circle, India's solar industry must break free from Chinese dependence, 2024
108.Bain & Company, India Electric Vehicle Report, 2023
109 World Bank Group, Transforming Finance to Meet Today's Development Needs, 2024

FIRESIDE CHAT

CHANGING GLOBAL GREEN ORDER: OPPORTUNITIES FOR INDIA

The fireside chat on **'Changing global green order: Opportunities for India'** was held between **Sumant Sinha,** Founder, Chairman and CEO of ReNew; **Henrik Skovby,** Founder and Global Chairman, Dalberg Group; **Dr. Ajay Mathur,** Director General, ISA; and **Manjeev Puri,** Former Ambassador of India to the EU, Nepal and the UN; and was moderated by **Ovais Sarmad,** Vice Chair of the Greenhouse Gas Protocol Steering Committee, Former Deputy Executive Secretary, UNFCCC.

The chat focused on India's opportunities to lead the global green transition by leveraging its domestic market, government policies, and technological expertise. It emphasized scaling cleantech manufacturing, enhancing R&D, fostering international cooperation, and addressing financing challenges to position India as a global clean energy leader and bridge between the Global North and South.

Context for fireside chat

The fireside chat convened an esteemed group of global thought leaders and practitioners to explore India's strategic positioning in a rapidly evolving global landscape of climate action. Against a backdrop of escalating climate crises, with 2024 being one of the hottest years on record, the discussion sought to dissect the critical pathways for India to emerge as a leader in the green economy. With themes of technology transfer, multilateral cooperation, and the dichotomy of the Global North and South, the speakers aimed to identify challenges and opportunities for India to leverage its resources, innovations, and diplomatic influence to redefine its role in the global green order. The conversation also addressed the geopolitical dynamics and the enablers necessary to transition from aspiration to action, emphasizing resilience, inclusivity, and leadership on the global stage.

Insights from the fireside chat

The speakers underscored India's dual role and its strategic positioning as a burgeoning market and a potential global leader in clean energy manufacturing. With strong government policies like the PLI schemes and a vast domestic market, they believe that India is well-positioned to develop its manufacturing capabilities in cleantech industries, such as solar, wind turbines, and batteries. However, challenges remain in competing with China's established cost and scale advantages. The speakers highlighted the need for India to focus on scaling up production, investing in R&D, and enhancing collaborations between industry and academia. This strategic shift could enable India to not only meet its domestic needs but also become a reliable exporter in a diversified global supply chain, especially as nations seek alternatives to China for strategic and risk management reasons.

Access to affordable capital emerged as a critical theme, with discussions emphasizing the higher cost of financing in the Global South compared to the North. The speakers highlighted the need for innovative financing mechanisms to reduce risks and attract global investment. Additionally, there is an urgent need to develop a domestic component ecosystem to reduce dependency on imports for essential parts like solar modules and batteries. Speakers also pointed out that opportunities in grid management, smart devices, and renewable energy integration present a natural advantage for India, given its strong engineering and tech sectors. However, achieving these goals requires focused investments in human capital, R&D, and infrastructure.

The conversation expanded to include India's role in the broader global green agenda, with its leadership in multilateral platforms like the International Solar Alliance (ISA) being a significant advantage. The speakers stressed that India's success is not just a domestic imperative but a global necessity, given the interconnected nature of climate action. India's ability to drive innovation in areas like grid management, green components, and renewable energy systems could set a benchmark for sustainable development globally. The emphasis was on leveraging India's soft power, diplomatic influence, and technical expertise to shape the global narrative on sustainable development and climate resilience.

In conclusion, the speakers underscored India's unique position to lead the global green transition by leveraging its vast domestic market, robust government initiatives, and growing technological capabilities. To fulfil this potential, it must address key challenges like scaling manufacturing, enhancing R&D through industry-academia collaboration, and ensuring access to affordable capital. India's leadership in platforms like the International Solar Alliance positions it to bridge gaps between the Global North and South, fostering innovation and cooperation. By balancing growth with sustainability, India can meet its climate commitments and emerge as a global clean energy leader.

MINISTERIAL ADDRESS AND LAUNCH OF BHARAT CLEANTECH MANUFACTURING PLATFORM: HONOURABLE MINSTER OF COMMERCE, PIYUSH GOYAL

The Ministerial Valedictory Address by Shri Piyush Goyal, Honourable Union Minister of Commerce, marked the conclusion of the Bharat Climate Forum and included the landmark launch of the Bharat Cleantech Manufacturing Platform. Shri Piyush Goyal emphasized India's remarkable achievements in renewable energy and outlined the roadmap for scaling up cleantech manufacturing as a pillar of India's journey toward sustainability, Atmanirbharta, and global leadership. His speech encapsulated the critical themes of policy innovation, clean energy adoption, and India's role as a global climate leader. A Memorandum of Understanding was also signed between Dalberg, the Council for International Economic Understanding, and the International Solar Alliance (ISA) in the presence of the Honourable Minister, to further the objectives of the Bharat Cleantech Manufacturing Platform.

In his speech, Shri Piyush Goyal highlighted India's exceptional performance with regards to its NDCs under the Paris Agreement. Notably, India achieved its target of having 40% of installed capacity from non-fossil energy sources by 2021, ahead of the earlier 2030 target.[110] He credited this success to visionary leadership, transparency in policy, and innovations like

110.PIB, India achieves target of 40% installed electricity capacity from non- fossil fuel sources, 2021

reverse auctions, which drastically reduced the cost of solar and wind power. From solar energy costing USD 0.12-0.14 per kWh (INR 10-12) in 2010-11, even with the Jawaharlal Nehru National Solar Mission (JNNSM), prices now are almost at a fifth of those levels, hovering around USD 0.028-0.03 per kWh, (INR 2.4-2.6) making renewable energy competitive with thermal power.[111] He celebrated India's rapid progress in achieving 200 GW of non-fossil energy installed capacity, on track to reach 500 GW by 2030, as announced by the Prime Minister at COP26.[112]

The Minister emphasized that India's cleantech journey is driven by Atmanirbharta—self-reliance in energy and manufacturing. He called for moving beyond subsidies and incentives, advocating for a business-driven approach that ensures long-term sustainability. He illustrated this with the transformative LED Bulb Program called UJALA, which evolved into the world's largest zero-subsidy domestic lighting programme.[113] This program not only reduced costs through transparency and scale but also showcased India's ability to innovate and implement efficient solutions that benefit millions.

The Honourable Minister launched the Bharat Cleantech Manufacturing Platform as a collaborative effort to foster innovation, resource sharing, and financing for cleantech manufacturing. This initiative aligns with India's broader goals of achieving net zero emissions by 2070, enhancing green manufacturing, and becoming a global hub for renewable energy technologies. He stressed that the platform's focus on co-innovation and partnerships would accelerate India's leadership in cleantech and sustainability.

Shri Goyal reiterated that India's young and skilled population, coupled with its vibrant democracy, rule of law, and robust infrastructure, makes it an attractive destination for global investment. He highlighted India's unique position as a bridge between the Global North and South, with its ability to drive equitable growth while addressing climate change challenges. With its 1.4 billion population and rapidly expanding economy, India offers unparalleled opportunities for businesses and investors, especially in clean energy and green manufacturing.

Shri Goyal shared lessons from India's energy sector transformation, including the integration of the national power grid, which resolved regional energy disparities and reduced costs. He underscored the significance of forward-thinking policies like the PLI scheme, which supports the manufacturing of solar panels, wind turbines, and other cleantech products. As the global focus shifts toward clean energy solutions, he ascertained that India is positioned to become a global leader in sustainability, providing innovative and scalable solutions.

Shri Piyush Goyal's valedictory address reinforced India's pivotal role in driving global sustainability through cleantech innovation and renewable energy adoption. By displaying substantial progress ahead of schedule on its renewable energy commitments for the Paris Agreement and launching transformative initiatives like the Bharat Cleantech Manufacturing Platform, India is setting benchmarks for other nations. Shri Goyal emphasized the importance of self-reliance, transparent policies, and business-driven solutions to ensure long-term growth. India's strategic investments in renewable energy, coupled with its youthful talent pool and robust infrastructure, position it as a global leader in cleantech manufacturing and a beacon of sustainable development. The Minister concluded with a call to action for all stakeholders to collaborate in building a prosperous, inclusive, and sustainable Bharat that embodies the vision of Viksit Bharat 2047.

111.Central Electricity Regulatory Commission New Delhi, 2012
112.Climate Action Tracker, NDC Updates, 2024
113.PIB, UJALA: 10 Years of Energy-Efficient Lighting, 2025

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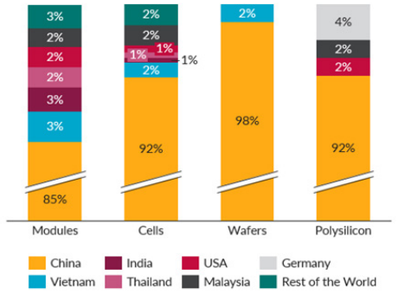
TECHNICAL ROUNDTABLE

LIGHTING THE WAY: SOLAR SOLUTIONS FOR A SELF-RELIANT BHARAT

Context and rationale

The global PV manufacturing landscape is highly consolidated, with the top five markets as shown in Figure 16. China controlling over 85% of the polysilicon, wafer, cell, and module production market share poses significant risks of supply chain disruptions, price volatility, and geopolitical tensions. China's supremacy is driven by vertically integrated supply chains, substantial economies of scale, and access to affordable RE, enabling cost efficiencies that remain unmatched by competing markets.[114,115]

Figure 16: Top PV Manufacturing Countries Market Share, 2023 (%)



In response to this monopolisation, countries like the USA and the European Union have introduced policies to reduce reliance on Chinese imports. The USA's Inflation Reduction Act[116] and the EU's Green Deal aim to bolster domestic production while incentivising investment in innovative solar technologies. These initiatives highlight a growing global commitment to reshaping the PV manufacturing landscape by fostering regional self-reliance and innovation. For countries such as India, this dynamic presents both a challenge and an opportunity. The confluence of China's dominance, coupled with intensifying competition and geopolitical risks, underscores the need for India to localise its solar manufacturing capabilities. By capitalising on its abundant human resources and policy frameworks such as the Production-Linked Incentive (PLI) scheme, India has the potential to emerge as a cost-competitive and reliable alternative in the global market. However, realizing this potential requires addressing structural supply chain gaps, investing in advanced manufacturing technologies, and ensuring consistent policy and financial support to build a robust and self-sufficient solar ecosystem capable of meeting domestic and international needs.

114.ISA Global Solar Supply Chain, 2023
115.GIZ-Deloitte Policy Roadmap for Solar Manufacturing in India, 2024
116.The Trump Administration has issued an Executive Order to repeal the IRA

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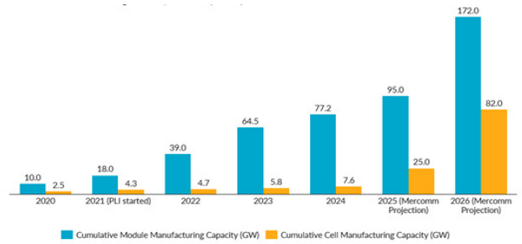
India's solar photovoltaic (PV) manufacturing sector is positioned as a key component of the country's ambition to become a global leader in clean technology manufacturing under its Viksit Bharat vision. The sector has achieved notable advancements, with an annual production capacity reaching approximately 80 GW for modules and over 7 GW for cells,[117] reflecting substantial progress in downstream manufacturing. This growth trajectory is illustrated in Figure 17. However, critical gaps in the upstream value chain—spanning polysilicon production, wafer fabrication, and cell manufacturing—present significant challenges to achieving self-reliance and global competitiveness.

Figure 17: India's PV Manufacturing Growth, 2020-2026 (in GW)



The upstream value chain in India remains heavily dependent on imports for 90% of polysilicon, wafers, and cells. This reliance inflates production costs and limits scalability, with manufacturing costs 30–40% higher than global benchmarks due to the absence of domestic polysilicon production and wafer fabrication capabilities. India's 3907.95 MMT silica-quartz reserves[118] remain untapped, while higher electricity costs USD 0.11/kWh (INR 9.3) vs. China's USD 0.076/kWh (INR 6.6)[119] further erode competitiveness. Module assembly operates at only 40–45% capacity utilization, meeting just 35% of domestic demand,[120] with heavy reliance on imports like 1.18 billion PV cells from China in 2024.[121] Additionally, India generates 34,600 tonnes of solar waste annually, lacking a robust recycling infrastructure to recover materials worth USD 11.6 Bn yearly. [122]

India's solar PV manufacturing sector faces critical challenges, including reliance on imported high-precision machinery like stingers, tabbers, texturization machines, and wire saws, which increases capital costs by 15–20% and undermines competitiveness.[3] Limited R&D investment, at less than 2% of annual revenues, further constrains the adoption of advanced technologies such as heterojunction (HJT) and tandem solar cells, critical for achieving higher efficiencies and cost reductions. Bridging these gaps requires robust domestic innovation hubs, increased funding, and strategic collaborations with global technology leaders to strengthen India's position in the global solar value chain. Workforce shortages and financial barriers further impede growth. India faces a 1.2 million skilled worker deficit, projected to rise to 1.7 million by 2027, particularly in advanced processes like wafer slicing and polysilicon refinement.[123] Despite initiatives like the Suryamitra Skill Development Programme, training efforts have not kept pace with the industry's expansion, slowing project timelines and escalating costs.

Overcoming these challenges requires strategic investments in upstream manufacturing, renewable-powered polysilicon production, and circular economy initiatives to reduce costs, enhance sustainability, and establish a globally competitive solar PV ecosystem.

Potential opportunities and challenges

India's PV manufacturing sector is poised for transformative growth, presenting numerous opportunities to enhance self-reliance, indigenise the solar value chain. The following themes outline key areas of opportunity:

- **Driving Self-Reliance and Net-Zero Goals:** Localising the solar value chain for energy-intensive processes like polysilicon and wafer production can reduce emissions and operational costs, aligning with India's 2070 net-zero target. Leveraging renewable energy in manufacturing could lower electricity costs from USD 0.11/kWh (INR 9.3) to USD 0.076/kWh (INR 6.6), matching global benchmarks and boosting sustainability.
- **Cost Stability and Resilience:** India imports 100% of its wafers and 60% of solar cells, creating bottlenecks and inflating production costs by up to 20%. Establishing domestic capacities for polysilicon and wafer production can mitigate global supply chain risks, stabilise prices, and enhance manufacturing resilience.
- **Indigenous Equipment Manufacturing:** Developing domestic capabilities for machinery

117.Central Electricity Authority National Electricity Plan 2022-32, MNRE
118.Indian Mineral Yearbook 2020, 2021
119.IEA, 2022
120.Mishra, 2024
121.Bloomberg NEF, 2024
122.GIZ-Deloitte Policy Roadmap for Solar Manufacturing in India, 2024
123.Bhattacharyya, 2024

such as stingers, texturizers, and wire saws can reduce capex by 15–20%, saving an estimated USD 175 - 233 Mn annually.[124] Collaborations with global OEMs can facilitate technology transfer, reducing reliance on imports and strengthening the local ecosystem.

- **Potential to become a Global Cleantech Manufacturing Hub:** India's strategic location, competitive labour costs, and renewable energy deployment position it as a preferred alternative to China for global solar manufacturing. The 'China Plus One' strategy and demand in emerging markets like Africa, Latin America, and Southeast Asia provide significant export opportunities.
- **Integrating Recycling for a Circular Solar Economy:** Establishing a robust recycling ecosystem can recover critical materials like silicon, silver, and glass, unlocking a USD 1.1 Bn annual market. Policies inspired by the EU's Circular Economy Action Plan, such as EPR, can enhance sustainability while creating 10,000+ green jobs.
- **Expansion of Domestic Ancillary Industries:** Developing ancillary components such as solar glass and encapsulation materials could reduce import dependency and unlock an annual market potential of USD 583 Mn. Collaboration with domestic industries can enhance vertical integration and support local manufacturing growth.
- **Digitalisation and Automation in Manufacturing:** Adopting smart manufacturing technologies like AI-driven process optimization, robotics, and IoT-based monitoring can improve efficiency and reduce waste by up to 20%, as demonstrated by global leaders like Germany. Public-private partnerships can fund digital transformation and position India at the forefront of Industry 4.0.

While the opportunities are immense, India's solar PV manufacturing sector faces multiple challenges that require strategic interventions:

- **High Production Costs:** India's solar manufacturing costs are 30–40% higher than global benchmarks due to high electricity tariffs, fragmented supply chains, and dependency on imported machinery.
- **Limited R&D Investments:** Indian manufacturers spend less than 2% of revenues on R&D, compared to 5–6% by global leaders, hindering innovation, adoption of advanced technologies and missing efficiencies exceeding 24–29%. Approximately 90% of India's solar manufacturing involves assembling imported cells, with only 15% local value addition.
- **Workforce and Skills Deficit:** Advanced processes like wafer slicing and polysilicon refinement require specialized skills, which are currently inadequate. Training programs such as Suryamitra need expansion to address high-tech manufacturing requirements.
- **Global Certification and Market Access:** Indian solar products face challenges in meeting stringent international certification standards, limiting exports to premium markets like EU.
- **Policy and Financing Gaps:** Delays and inconsistencies in implementing schemes like the PLI and ALMM create uncertainty for investors. Additionally, the absence of long-term policy roadmaps for ancillary industries limits growth. High borrowing costs (12–15%) and limited concessional financing options deter private sector participation in upstream manufacturing investments.
- **Underdeveloped Recycling Ecosystem:** The absence of a comprehensive solar waste recycling ecosystem limits sustainability efforts. Unlike the EU, which has integrated recycling into its solar policies, India needs to develop infrastructure and policies to support PV module recycling.
- **Global Partnerships on Technology and Investments Constraints:** Strengthening global trade ties and securing foreign direct investments are key to scaling India's solar PV manufacturing. Collaborations, like the Indo-US Clean Energy Partnership or EU's Green Deal, can drive technology transfer and market access. Aligning domestic practices with international standards and forming partnerships for critical raw materials, such as silica from Africa and the Middle East, are essential to ensure supply chain resilience and unlock growth.

Moderators & Participants

TERI and **NSEFI (National Solar Energy Federation of India)** are the knowledge partners for Solar sector for Bharat Cleantech Manufacturing Platform and Bharat Climate Forum.

The technical roundtable discussion was moderated by **A.K. Saxena, Senior Director, TERI.**

124. ET Energy world, 2024

Bharat Climate Forum 2025

The participants for the roundtable included:

Roundtable Participants	Title, Organisation
Abhishek Shah	Partner KPMG
Abinav Mahajan	Director, IB Solar
Aditya Goel	CEO, Ornate Solar
Ajay Mathur	Director General, ISA
Devesh Tripathi	Sr. Assistant Vice President, Global Partnerships, Invest India
Dr. Jaiprakash Singh	Deputy DG, NISE
Kanv Garg	Chief Growth Officer, Gensol Group
Kunal Saxena	Head- Strategic Investments, AMPIN Solar One Private Limited
Prafulla Pathak	President, Solar Energy Society of India
Prashant Choubey	President, Avaada Group
Praveen Kumar	Director General, All India Solar Industries Association (AISIA)
Rishabh Jain	Senior Programme Lead, CEEW
Shashank Shekhar Garuryar	Vice President & Head, ACME Solar Holdings Ltd.
Upendra Tripathy	Former DG, International Solar Alliance,

Key insights from the roundtable

During the roundtable, participants discussed key challenges hindering the growth and global competitiveness of India's solar sector. Prominent among these were significant manufacturing gaps in the value chain, particularly in the production of polysilicon, ingots, and wafers, which have resulted in heavy reliance on imports and inflated production costs. The inefficiencies in translating demand into installations were also highlighted, with backlogs in tenders and projects being a major concern. Duties and government interventions, such as the new anti-dumping duties on solar glass could be effective in addressing ecosystem misalignments.

The discussion further explored the sector's low investment in advanced technologies like heterojunction and tandem cells, along with the absence of sufficient private sector incentives for research and development (R&D). Financial barriers, including high capital costs and lack of synchronised financial policies, were perceived as additional constraints that hinder the scaling of manufacturing and installations. Additionally, the concentration of global production in countries like China was seen as a significant source of supply chain vulnerabilities. Participants also noted that limited international collaborations and missed opportunities for ecosystem partnerships restrict India's ability to expand its footprint in emerging markets.

A few potential measures to address these challenges were also discussed, the PLI on High Efficiency Solar PV Modules could address 48 GW capacity but the path beyond that to increase manufacturing capacity at competitive costs is unclear. Participants had a call to action for increasing R&D investments and potentially incentivizing them through fiscal incentives, guidelines mandating R&D investments by private sector from a share of profits (similar to CSR), and collaborations between academia and industry. Aligning duties with production timelines, promoting cluster manufacturing to reduce logistics costs, and investing in quality control infrastructure were also discussed as necessary measures to enhance export readiness.

There was strong advocacy for prioritizing emerging technologies, such as perovskite-silicon tandem cells and heterojunction cells, to secure a competitive edge in the global market. Currently, key raw materials for these technologies such as high-purity lead halides, organic hole transport materials, and iridium tin oxide, are either not produced locally at scale or require significant infrastructure for refining at the required quality levels. However, these can be developed through targeted investments in refining technologies, explorations for critical minerals, and partnerships to enhance local supply chains.

Strategies to expand market reach were discussed, such as partnering with global players in Africa, Latin America, and other emerging markets, as well as establishing overseas manufacturing units. The creation of a robust solar panels and modules recycling ecosystem was also identified as a key step towards ensuring resource recovery, optimizing resource utilization and end-of-life management.

Participants highlighted the need to attract global investors, promote green bonds, and enhance collaboration among stakeholders such as developers, manufacturers, and DISCOMs to drive growth and efficiency in the solar sector. The need for a skilled workforce was also recognized. Skill development programs, such as those offered by NISE were seen as key to addressing this issue, though the awareness of the programs like Suryamitra seemed low among the industry. These discussions underscored the importance of coordinated efforts to position India's solar sector for long-term success and competitiveness.

TECHNICAL ROUNDTABLE

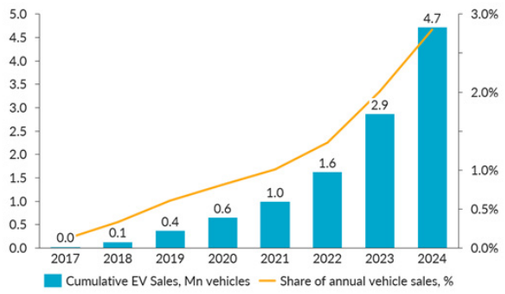
CHARGING AHEAD: BHARAT'S JOURNEY TO GREEN MOBILITY SELF-RELIANCE

Context and rationale

EVs are pivotal to India's ambitions of achieving energy independence by 2047 and net-zero emissions by 2070, as outlined under the Panchamrit targets. Moreover, the growing EV market positions India as a potential global leader in EV manufacturing, leveraging its large domestic market, cost-competitive production, and policy-driven investments aligned with the Atmanirbharver, the growing EV market positions India as a potential global leader in EV manufacturing, leveraging its large domestic market, cost-competitive production, and policy-driven investments aligned with the Atmanirbhar Bharat vision.

India is witnessing rapid growth in EV adoption. In FY 2023–24, EVs accounted for 6.8% of total vehicle sales,[125] with an ambitious target of achieving 30% EV sales penetration for new vehicles by 2030,[126] equating to 102 million EVs on the road.[127] This progress is driven by central and state-level policies, including the PM e-Drive, FAME II scheme, and Production-Linked Incentive (PLI) programs, alongside advancements in technology and increasing EV model availability. However, sustaining this growth requires securing a localized EV value chain, particularly in battery manufacturing, recycling infrastructure, and upstream material processing.

Figure 18: EV Share of sales in India 2017-2024



India has made significant strides in developing local manufacturing capabilities for EV, supported by a robust foundation of policies, strategic partnerships, and growing market potential. The key enablers that are accelerating cleantech growth and drive the localisation of EV assembly, battery cell manufacturing, and power electronics production include:

1. **Policy Support:** Initiatives like the PLI scheme for advanced automotive components, motors, and power electronics offer financial incentives to scale domestic production, fostering competitiveness and growth.
2. **Strategic Partnerships:** Collaborations with technologically advanced nations such as Japan, Germany, and South Korea enable access to critical resources, facilitate technology transfer, and bolster export-oriented manufacturing capabilities.
3. **Expanding Domestic Market:** India's EV market, projected to reach 102 million vehicles by 2030, is driving demand for localized manufacturing and spurring innovation in the value chain.[128]
4. **Circular Economy Development:** Building robust recycling infrastructure for components like motors and semiconductors enhances resource recovery, reduces import dependency, and promotes sustainability across the EV ecosystem.
5. **Emerging Export Potential:** Export opportunities to emerging markets in Africa and Southeast Asia, where EV demand is expected to grow by over 20% annually, position India as a competitive global manufacturing hub.[129]

However, globally, the EV supply chain remains concentrated, with China controlling over 70% of global lithium refining capacity and 60% of battery cell manufacturing, alongside key components such as motors and charging infrastructure.[130] This dominance exposes India to risks like supply disruptions and price volatility, which could hinder its ability to scale EV adoption and ensure energy security.

Potential opportunities and challenges

The transition to a cost-competitive cleantech supply chain offers India transformative opportunities to achieve economic growth, technological leadership, and sustainability in the global EV market.

1. **Accelerating Net-Zero Transition:** Localising the EV value chain, including motors, power electronics, and charging infrastructure, supports India's net-zero emissions goal by 2070 while addressing transportation's 14% contribution to greenhouse gas emissions.[131]
2. **USD 206 Bn Domestic Market Opportunity:** The domestic EV market in India is projected to offer an estimated USD 206 Bn in cumulative revenue opportunities by 2030, driven by a growing demand for EVs, supportive government policies, and advancements in technology, creating a robust platform for local manufacturing and innovation.[132]
3. **Reducing Import Dependency:** Manufacturing rare earth-based motors, inverters, and semiconductors domestically can stabilize 50,000 jobs by 2030, spanning R&D, production, and assembly.[133]
4. **Technological Advancements:** Investments in high-efficiency motors, interoperable charging systems, and power electronics tailored to India's conditions can lower costs and improve EV performance.
5. **Reducing Import Dependency:** Manufacturing rare earth-based motors, inverters, and semiconductors domestically can stabilize costs and reduce risks from global supply chain disruptions.
6. **Positioning India as a Global Manufacturing Hub:** India has the potential to achieve a USD 70 Bn export opportunity by 2030, targeting emerging markets such as Africa and Southeast Asia, where EV demand is projected to grow at over 20% annually.[134]

125.Business Standard, Despite subsidy cuts, EV sales zoom 41% in FY24; penetration at 6.8%
126.GoI, Office of the Principal Scientific Advisor, Electric Vehicles Mission
127.Vahan Dashboard, Ministry of Road Transport and Highway (MoRTH), January 2024 and RMI Analysis, 2024
128.CEEW, Financing India Transition to Electric Vehicles
129.LeapFrog Investments Analysis, Singapore, July 2023
130.Organization for research on China and Asia, 2024 and Reuters, 2024
131.Strategies for achieving net-zero emissions, Press Bureau of India (PIB), August 8, 2024
132.CEEW, Financing India Transition to Electric Vehicles
133.EV industry can reshape India employment landscape, Down to Earth, Center of Science and Environment (CSE), April 2024
134.LeapFrog Investments Analysis, Singapore, July 2023

However, multiple challenges could hinder this progress and need to be addressed in order to leverage the opportunities.

Despite the several enabling factors and advancements, India's value chain remains partially localized, and the ecosystem continues to heavily rely on imports including lithium-ion batteries, raw materials like lithium, cobalt, and nickel, rare earth elements for motors, semiconductor chips, and power electronics. Addressing these gaps is crucial, as achieving energy independence in mobility by 2047 could save India an estimated USD 1.92 Tn (INR 160 lakh crore) in crude oil imports.[135]

1. **Achieving Cost Competitiveness:** Scaling domestic production of motors and power electronics involves significant capital investments, such as the USD 3–4 Bn required for semiconductor manufacturing facilities. Competing with lower-cost imports, particularly from China, remains a key challenge despite initiatives like the PLI scheme.[136]
2. **Closing R&D and Technological Gaps:** India's investment in cleantech R&D is relatively low, at less than 0.5% of GDP, compared to global leaders like China (2.2%)[137] and the US (2.8%). Bridging the gap between research and commercialization is critical for self-reliance in power electronics and motor technologies.[138]
3. **Addressing Workforce and Skilling Deficits:** The demand for skilled professionals in motor assembly, semiconductor design, and charging system integration exceeds the current availability. Tailored skilling programs and capacity-building initiatives are essential to meet industry needs.
4. **Attracting Investments and Fostering Partnerships:** Regulatory uncertainties and competition from other nations hinder India's ability to attract foreign direct investments for motor manufacturing and charging infrastructure development. Strengthening FDI policies and creating a predictable investment environment are crucial for growth.
5. **Overcoming Financing Constraints:** Financing large-scale production facilities for motors, power electronics, and charging systems remains a bottleneck. High borrowing costs (exceeding 9% for industries) and limited concessional finance options restrict SME participation in the supply chain.
6. **Ensuring Resource Access and Supply Chain Stability:** India's dependence on imports for rare earth materials and semiconductors exposes it to supply chain disruptions and price volatility. Establishing strategic resource partnerships with countries like Australia and Chile is essential to address these vulnerabilities.
7. **Strengthening Infrastructure and Ecosystem Development:** Existing infrastructure for motor manufacturing, semiconductor production, and charging system integration is inadequate for rapid scale-up. Investments in advanced manufacturing facilities, recycling systems, and interoperability standards are necessary to support the growing EV ecosystem.

Moderators & Participants

INTENT and **Rocky Mountain Institute (RMI)** are the knowledge partners for E-mobility sector for Bharat Cleantech Manufacturing Platform and Bharat Climate Forum.

The technical roundtable discussion was co-moderated by **Mahua Acharya, Founder, INTENT, Ex-MD and Ex-CEO of Convergence Energy Services Limited**, and **Akshima Ghate, MD India, Rocky Mountain Institute.**

The participants for the roundtable included:

Roundtable Participants	Title, Organisation
Akshay Shekhar	Co-Founder & CEO, Kazam EV
Anirudh Arun	Co-founder and CEO, BluSmart
I V Rao	Distinguished Fellow, Transport & Urban Governance, TERI
Kulbhushan Kumar	Partner, Grant Thornton Bharat
Nishant Idnani	Managing Director, Vaultus Green Funding
Pramod Sharma	Chief Operating Officer, Sun Mobility
Ripu Bhanjan Singh	Senior Director, US India Strategic Partnership Forum (USISPF)
Subrata Mitra	Sr. Vice President - Head Government Relations and Policy, Ather Energy
Sudipto Shome	VP and Head of 3W Operations, Zypp Electric

135.India and 2047: Mobility, RMI Analysis 2024
136.Reuters, September 2024 and production Linked Incentive (PLI) Scheme for Large Scale Electronics Manufacturing, Ministry of Electronics and Information Technology (MEITy) 2024
137.ChinaPower Project, Is China a Global Leader in Research and Development?
138.Economic Survey of India, 2024 and World Intellectual Property Organization (WIPO) and Global Innovation Index Survey, July 2024

Key insights from the roundtable

Participants highlighted significant developments in the charging infrastructure sector, noting the shift in focus among Charge Point Operators (CPOs) from slow to fast public charging, particularly for two- and three-wheelers, while personal charge points for three-wheelers have become more common. A key area of discussion was interoperability, with the Unified Electric Interface (UEI) emerging as a promising solution. The UEI leverages a single API to address integration challenges, but participants flagged the lack of standardized charging protocols as a major gap. They also emphasized the need for a centralized data hub, similar to NPCI for UPI, to support interoperability while ensuring data confidentiality.

On government policies, attendees discussed the ambitious targets for charging infrastructure installation and the PM E-Drive scheme's USD 230 Mn (INR 2,000 crore) allocation, which could scale up to USD 1.16 Bn (INR 10,000 crore) with private sector participation. However, concerns were raised about the current DISCOM funding model, which is not well-suited for small EVs like two-wheelers. These vehicles require smaller, low-cost, more distributed charging points, but DISCOMs are neither structured to fund nor prioritize such micro-level investments. Additionally, the 18% GST on battery replacement was highlighted as a significant barrier to the adoption of battery-swapping solutions.

One of the potential operational solutions discussed was regarding the importance of improving Service Level Agreements (SLAs) between DISCOMs and charging infrastructure providers to ensure reliable power supply and boost user confidence was underscored. Additionally, the role of large super hubs in cities capable of simultaneously charging 40–60 vehicles was highlighted. Finally, participants agreed that access to home charging is critical to accelerating EV adoption.

On indigenizing India's electric vehicle value chain, participants stressed the need for advancements in battery technology, with solid-state and aluminium-air batteries identified as promising innovations. The lack of leadership in R&D and the need for tech-agnostic standards from the Bureau of Indian Standards (BIS), were also discussed. Reliance on imported batteries and critical minerals, particularly from China, was seen as a major challenge, raising concerns about material quality and supply chain dependency. Attendees debated the cost competitiveness of Indian-made batteries and questioned whether consumers would pay a premium for locally manufactured products.

On the issue of batteries, the need for trade missions and supply chain policies to attract foreign investment, secure critical materials, and bridge knowledge gaps was another key topic. Discussions also focused on the importance of battery recycling policies, noting the imminent need to establish formal recycling systems for millions of batteries. In addition to existing initiatives such as EPR, the participants were in favour of retaining recycled materials like black mass domestically, supported by PLI schemes and other measures like tracking Battery 'passports.'

Participants concluded that large-scale funding from institutional investors, coupled with innovative financing solutions and strengthened public-private R&D collaborations, is also important to achieve indigenization in EV manufacturing.

TECHNICAL ROUNDTABLE

HARNESSING THE WIND: LOCAL SOLUTIONS ACROSS THE WIND ENERGY VALUE CHAIN

Context and rationale

India has emerged as a key player in the global wind energy supply chain, leveraging its growing manufacturing capabilities to contribute significantly to the international markets while simultaneously advancing its domestic renewable energy agenda. As the fourth largest exporter of wind-powered electric generators, India's wind energy exports were valued at USD 472 Mn in FY 24, with shipments reaching approximately 20 countries, including major markets in Europe, the Americas, and Australia. In recent years, exports have surged, with nacelle exports increasing from 1.7 GW in FY 22 to 3.9 GW in FY 24. Additionally, India has become a major supplier of wind turbine blades, with total blade exports reaching 9.6 GW in FY 24, primarily to the EU and the US.[139]

While India has made impressive strides on the global stage, its domestic wind energy sector has also experienced significant growth. With an installed wind capacity of 47.9 GW, India ranks fourth globally in wind energy capacity, driven by the country's vast coastal and inland wind corridors.[140] This growth has fostered the development of a robust ecosystem and manufacturing base, with an annual production capacity of around 18,000 MW. The wind sector employed about 52,200 people, with nearly 40% of these jobs in operations and maintenance and 35% in construction and installation.[142] India has set an ambitious target to achieve 100 GW of installed wind capacity by 2030, underscoring the continued need for investment, innovation, and policy support to meet this goal.

India stands as one of only five countries worldwide capable of producing all six major wind turbine components: nacelles, blades, towers, generators, gearboxes, and bearings.[143] The country's wind turbine blade manufacturing capacity places it alongside China as one of the world's two primary centres for blade production. With ample production capacity and continued investment, India is well-positioned to meet global demand for wind turbine components for the decade 2023–33.

Figure 19: Installed Wind Energy Capacity in India

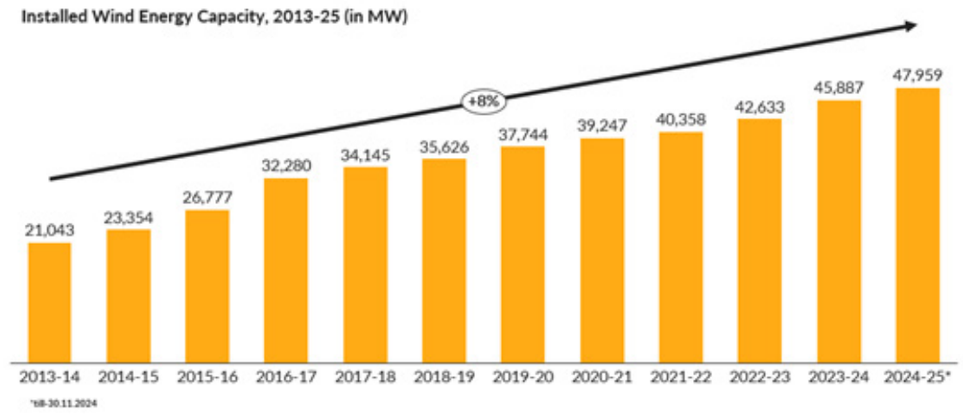
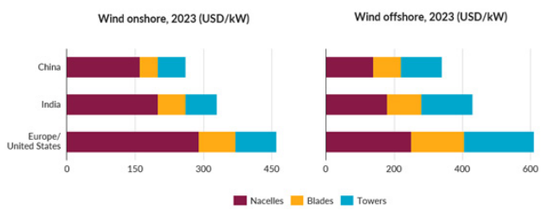
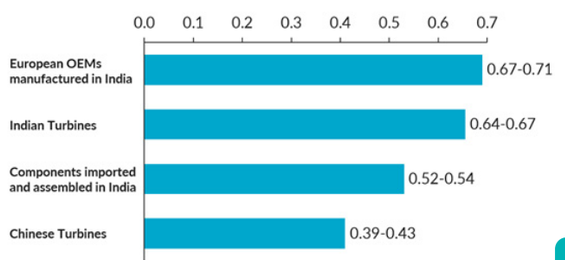


Figure 20: Regional cost differential for wind energy components for onshore and offshore projects



Despite its technological capabilities, India still imports a significant number of wind turbine components such as gearboxes, generators, converters, and bearings, even though domestic suppliers exist. India's reliance on imports for certain wind turbine components is due to several factors. One major reason is the cost differential between India and countries like China, where large-scale manufacturing and government subsidies have led to a more competitive cost structure. Additionally, certain tier-2 components, such as main shafts, pitch and yaw bearings, hubs, and mainframes, are often imported due to the limited number of domestic manufacturers capable of producing these specialized parts at the required scale. Furthermore, many components in India are produced in subscale manufacturing setups, limiting production capacity. Domestic capabilities are also restricted in certain processes, such as forging and large castings. As a result, the local value addition in wind turbine generators (WTGs) installed in India, as well as the export of WTG components, remains limited, ranging from 20% to 40% as of FY24.[144] India has established several enablers to promote domestic manufacturing of critical wind energy components, strengthening the supply chain. These include financial incentives such as customs duty exemptions on specific raw materials, the Remission of Duties and Taxes on Exported Products (RoDTEP) scheme, which

Figure 21: Cost comparison of wind turbines (EUR Mn/MW)



139.MEC+ Intelligence
140.Government of India, Ministry of New and Renewable Energy, Programme/Scheme wise Cumulative Physical Progress as on November, 2024
141.Government of India, Ministry of New and Renewable Energy, Wind Overview
142.Ministry of New and Renewable Energy, India's Renewable Energy Capacity Hits New Milestone, 2024
143.Global Wind Energy Council, From Local Wind Power to Global Export Hub, 2023
144.MEC+ Intelligence

provides exporters with refunds on taxes and duties, and the notification of models under the Revised List of Models and Manufacturers (RLMM).

However, to enhance the cost-competitiveness of indigenizing the wind energy supply chain and boost export capabilities, India must address several key challenges. These include a lack of advanced skills and technologies for modern manufacturing processes, a sub-scale manufacturing ecosystem compared to China—which results in higher production costs—and logistical and infrastructure hurdles in handling and transporting larger components, compounded by limited access to market-ready infrastructure.

Potential opportunities and challenges

The opportunities for driving indigenization of wind energy value chain and improving self-reliance include:

- **Lower import duties on raw materials:** Wind component manufacturing in the country relies on the import of certain raw materials that are not produced or harvested domestically, such as non-standard steel, permanent magnets, and balsa wood. Reducing import duties or even offering duty waivers for raw materials and certain work-in-progress goods could enhance the competitiveness of India's wind manufacturing sector, both regionally and globally.
- **Promote domestic innovation in wind manufacturing:** Currently, wind turbine prototypes are mostly developed and tested outside of India. Implementing measures to encourage domestic development, testing, and R&D of prototypes, such as offering innovation grants, could help stimulate local investment in the supply chain and support the growth of wind manufacturing in India.
- **Introduce a targeted PLI scheme for the wind sector:** While India has a strong wind manufacturing base, there are areas where a greater push is required to further support manufacturing for both domestic and export markets. Introducing a PLI scheme to incentivise investment in castings, gearbox, nacelle assembly and other components could increase the vertical integration of the domestic manufacturing industry.
- **Leverage Free Trade Agreements (FTAs) to strengthen the position in the wind exports market:** The central and state governments may consider the design and implementation of wind exports corridors to support enhanced logistics support and lower trade barriers for domestic manufacturers.
- **Green Workforce:** It is estimated that India can create about 150,000 jobs in wind by 2030 if its clean energy goals are achieved.[145] These jobs will span various sectors, including manufacturing, project development, construction, operations, and maintenance (O&M), and installation. Thus, building the capacity of vocational and higher education institutions in wind energy-related curricular structures can aid the workforce transition.

The challenges to addressing these opportunities exist across multiple areas:

- **Cost Competitiveness:** The cost of manufacturing wind turbines in India is significantly higher than in China. The Chinese wind industry has invested heavily in manufacturing technology, and raw materials like steel are available domestically at a cheaper rate than the other regions. Consequently, China has achieved economies of scale that enables it to produce turbines at a 30% lower cost than of locally assembled Indian turbines.[146]
- **Dependence on imports:** The challenge of unavailability of components, including large castings, generators, and other critical components, can pose significant challenges for the wind supply chain in India, which in turn leads to a significant cost difference in the turbine components, including blades, towers, and gearboxes, as compared to China. These components contribute ~55% of the total cost of turbines, and a significant cost difference of almost USD 0.10 - 0.12 Mn per MW (INR 0.9 - 1 crore) between Indian and Chinese wind turbines.[147]
- **High-cost pressures on domestic equipment manufacturers:** Between 2020 and 2022, India witnessed a 10-12% increase in the generation costs of wind projects, causing the Levelized Cost of Energy (LCOE) to rise from USD 0.032-0.038 per kWh (INR 2.8-3.3) in 2020 to USD 0.037-0.047 per kWh (INR 3.2-4.1) in 2022.[148] This cost increase can be attributed to the rising costs of raw materials, including steel and aluminium, logistical bottlenecks, inflation, and taxes levied on wind turbines. The increase in the price of steel, a key component accounting for over 70% of the raw materials used for turbines, significantly contributes to this cost difference.
- **Workforce Gaps**: The wind power sector is more labour-intensive than solar, requiring a higher level of technical qualifications and skills to build turbines and construct and maintain wind farms. However, training programs like Vayumitra focus only on entry-level training and do not offer specialized design training.

Moderator & Participants

MEC+ is the knowledge partner for the Wind sector for Bharat Cleantech Manufacturing Platform and Bharat Climate Forum.

The technical roundtable discussion was moderated by Sidharth Jain, Founder and MD, MEC+.

The participants for the roundtable included:

Roundtable Participants	Title, Organisation
Annika Seiler	Lead – Clean Energy Supply Chains, ADB
Balram Mehta	Group President, ReNew
Daya Sagar	DGM, Avaada Group
Madhusudan Khemka	MD, ReGen Powertech
Prashant Choubey	President, Avaada Group
Pulak Srivastava	GM, BC Jindal Group
Vinay Rustagi	Former MD, Bridge to India
Vivek Srivastava	India CEO, Suzlon Energy

Key insights from the roundtable

The discussion focused on various challenges towards indigenizing the wind energy industry in India, including demand dynamics, supply chain challenges, and the role of government support. Participants highlighted that despite increasing popularity of Solar PV projects and declines in the cost of battery storage, there was still strong demand for Wind Energy power in the renewable energy mix, noting that wind is needed to provide two cycles of renewable energy supply, as solar can only provide one cycle.

They noted that while macro level demand was high, execution challenges have slowed installations. With large-scale wind projects often requiring multiple sites, e.g. 250 sites for a 1 GW project, logistical issues are a major challenge. Grid connectivity issues in states such as Gujarat, Tamil Nadu, and Maharashtra were also highlighted, with participants stressing that the lack of coordination between State and local authorities exacerbates these difficulties. These issues led to delays and discouraged investments in the manufacturing supply chain, driving preference for less challenging alternatives such as solar PV projects.

Another key issue discussed was cost competitiveness with regards to imports. Policy and regulatory support were identified as essential to address competitive gaps, similar to other energy sectors like solar and E-mobility. The wind energy sector has relatively fewer barriers to imports. They emphasized the need for import barriers and incentives such as ADDs and structural barriers to boost domestic production and align India's policies with those of other competitive markets. It was noted that, without these interventions, investors hesitate to expand local manufacturing capacities. Participants suggested requiring major OEMs to prepare phased manufacturing plans to ensure higher domestic value addition over time, targeting 70–80% local manufacturing within four years.

On the issue of assembling imported components in India, participants highlighted that China's larger-scale manufacturing facilities and dedicated logistics provide cost advantages that India currently cannot match. India's smaller production scales lead to higher costs, deterring investments, seen even in other sectors like steel. Furthermore, innovation in wind technology and R&D remain underfunded, as limited domestic demand does not justify significant investments in new technologies.

The potential for exports was also addressed, with participants noting that domestic demand must be firmly established before expanding to international markets. A strong domestic baseline is essential to achieve competitive costs and build economies of scale.

145.CEEW, India's Expanding Clean Energy Workforce, 2022
146.Global Wind Energy Council, From Local Wind Power to Global Export Hub, 2023
147.Global Wind Energy Council, From Local Wind Power to Global Export Hub, 2023

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Bharat Climate Forum 2025

148.Global Wind Energy Council, From Local Wind Power to Global Export Hub, 2023

TECHNICAL ROUNDTABLE

THE HYDROGEN OPPORTUNITY: CAN INDIA LEAD THE GLOBAL SHIFT?

Context and rationale

Recognising green hydrogen's significance in achieving climate goals, 64 countries worldwide have developed strategies, roadmaps, and policies to advance green hydrogen in their economies.[149] To achieve global net zero goals, green hydrogen demand would need to increase ~6x by 2050, which will require establishing a 3000 GW electrolyser capacity by 2045.[150] Green hydrogen is integral to achieving net zero goals in India, too, and demand is expected to increase fourfold by 2050.[151] India's National Green Hydrogen Mission (NGHM) by the Ministry of New and Renewable Energy (MNRE), with a budgetary outlay of USD 2.5 Bn (INR 19,740 crore), along with the Green Hydrogen Policy by the Ministry of Power and dedicated green hydrogen, industrial and renewable energy policies of twelve states provide an impetus to the sector's trajectory.

Although the green hydrogen sector is in the nascent stages of development, India is proactively trying to indigenise the entire value chain through a host of policy measures. It has enacted production-linked incentives (PLI) for domestic manufacturing of renewable energy (RE) and electrolyser manufacturing, as well as import duties and an approved list of models and manufacturers (ALMM) decree for RE components. India's focus on promoting indigenously developed electrolyser technology is also apparent through the special provisions in the PLI scheme bidding tranches. Furthermore, green hydrogen has also been classified as a 'thrust sector' accruing special incentives such as capital subsidies, interest subventions, and tax incentives in the state industrial policies of Gujarat, Tamil Nadu, Odisha, Rajasthan, etc.

India's advantages in green hydrogen manufacturing lie in its well-established industrial base with strong engineering capabilities, a large pool of skilled engineers and technicians, low labour costs, and a concerted push from India's central and state governments to promote high-end manufacturing. Further, the cost of renewable energy in India has dropped dramatically over the past decade, making it one of the world's most cost-effective sources of clean power.

To truly capitalise on these advantages, India must bridge a few critical gaps. The most prominent gap is India's dependence on imports of core technologies like membranes for electrolysers and specialised solar-cell components. India also needs to import critical minerals as it lacks the reserves and processing capabilities for these precious materials. It must elevate its power electronics and semiconductor industry. Finally, it must find ways to reduce the high cost of capital observed to range between 9 -11% in India.[152]

Potential opportunities and challenges

Worldwide, the green hydrogen value chain is still in its nascent stages of development, with many countries exploring how to establish a sustainable, cost-effective, and scalable hydrogen economy. The value chain, comprising the electrolyser and RE technology and the infrastructure to store, move and use green hydrogen, poses unique opportunities and challenges to each country.

India has many opportunities in the green hydrogen sector to advance its broader strategic goals and accelerate the net zero transition. Some of these include:

- **RE and electrolyser manufacturing:** According to CEEW estimates, meeting the projected green hydrogen demand of 29 MTPA by 2050 will require an additional 650–700 GW of RE capacity and 220-230 GW of electrolyser capacity. This will require an investment of USD 340 Bn by 2050, which will reduce 3.6 GT of cumulative CO2 emissions.[153]
- **Manufacturing of supporting infrastructure:** Infrastructure for RE transmission, green hydrogen storage, transportation and end-use application systems will further entail developing commensurate manufacturing ecosystem and open up new investment opportunities to square the trinity of jobs, growth and sustainability.
- **Investment and jobs:** The NGHM targets securing investment of USD 93 Bn (INR 8 lakh crore), leading to 0.6 million jobs by 2030, both of which could grow multi-fold by 2050.[154]
- **Export opportunities:** India can leverage its potential to be a cost-competitive producer to export green hydrogen and derivatives to developed countries in Europe and East Asia that do not have a suitable RE profile[155] Further, Indian companies are setting up electrolyser gigafactories that can service international markets.
- **Stability in energy prices:** Reduced dependence on fossil fuels, thereby reducing energy price volatility due to geopolitical tensions and international supply or demand disruptions.
- **Revenues and low-cost capital through carbon credits:** India is catalysing the offtake of clean fuels from India through multiple bilateral partnerships. Under Article 6.2 of the Paris Agreement, five of the thirteen technologies considered for trading carbon credits are related to green hydrogen.[156] This enables India to produce and consume green hydrogen within India and earn a premium by sharing carbon credits with other countries.

The following key challenges to indigenisation will require a concerted effort to be overcome.

- **Reliance on imports of core technology and critical minerals:** The biggest impediment to India's cost competitiveness and manufacturing capabilities in the green hydrogen sector is the lack of access to technology like membranes in electrolysers and critical minerals. Excluding the value of these components, CEEW analysis finds that the overall indigenisation potential for all types of electrolysers can exceed 80 per cent in India.[157]

149.CSIRO - Hyresource. International. Policies. Accessed on Dec '24.
151.IEA (2021). Net Zero by 2050. IEA. Paris.
152.Raj, Kowtham, Pranav Lakhina, Clay Stranger. June 2022. Harnessing Green Hydrogen: Opportunities for Deep Decarbonisation in India. Niti Aayog and RMI. New Delhi.
153.Raj, Kowtham, Pranav Lakhina, Clay Stranger. June 2022. Harnessing Green Hydrogen: Opportunities for Deep Decarbonisation in India. Niti Aayog and RMI. New Delhi.
154.MNRE. Jan 2023. National Green Hydrogen Mission. MNRE. New Delhi.
155.Mallya, Hemant, Deepak Yadav, Anushka Maheshwari, Nitin Bassi, and Prerna Prabhakar Unlocking India's RE and Green Hydrogen Potential: An Assessment of Land, Water, and Climate Nexus. New Delhi: Council on Energy, Environment and Water.
156.Ministry of Environment, Forest and Climate Change. 2023. Activities finalised to be considered for trading of carbon credits under Article 6.2 mechanism to facilitate transfer of emerging technologies and mobilise international finance in India.
157.Patidar, Rishabh, Deepak Yadav, and Hemant Mallya, 2024. How can Hydrogen Electrolysers be Made in India? A Bottom-up Cost Assessment to Quantify the Indigenisation Potential. New Delhi: Council of Energy, Environment and Water.

- **R&D and innovation challenges:** Mission-mode projects aimed at this specific objective are required to leverage the MNRE's R&D allocation of the NGHM to advance indigenisation. India also needs to facilitate the transfer of core technologies through international partnerships.
- **High cost of finance:** India's high cost of capital, mostly between 9 and 11 percent, puts India at a disadvantage compared to developed countries and China. This difference in the cost of capital results in a difference in the levelized cost of green hydrogen between the countries. G2G structures and innovative contracting mechanisms to allay the risk associated with emerging economies need to be leveraged to reduce this cost of capital.
- **Skill gap:** India lacks engineers and scientists with specialised knowledge of green hydrogen. Further, workers need to be trained in the green hydrogen sector, especially in areas like plant operation, system integration, and maintenance.
- **Ecosystem challenges:** The lack of shared public resources and infrastructures that address intangible aspects such as India-specific standards, testing facilities, internationally compatible certification mechanisms, databases of suppliers and original equipment manufacturers (OEMs) and knowledge products is a challenge. These aspects must be developed in India to make the most of its unique advantages and not be susceptible to norms that suit other countries.

Moderator & Participants

The **Council on Energy, Environment and Water (CEEW)** is the knowledge partner for the Green Hydrogen sector for Bharat Cleantech Manufacturing Platform and Bharat Climate Forum.

The technical roundtable discussion was moderated by **Deepak Yadav, Senior Program Lead, Council on Energy, Environment and Water (CEEW).**

Bharat Climate Forum 2025

The participants for the roundtable included:

Roundtable Participants	Title, Organisation
Anuj Sharma	CEO, Hydrogen Business, Waaree
Arjun Mehta	Senior Advisor, GH2 India
Ashish Gupta	DGM (HSSE), BPCL
Gurpreet Chugh	MD, India, ICF
Ms Surbhi Goyal	Senior Energy Specialist, The World Bank
Navdeep Gupta	General Manager - Strategic Business Development & Policy, ReNew
Nishaanth Balashanmugam	Director, GH2 India
Pankaj Kumar Gupta	General Manager (Energy Transition and Policy Research), NTPC
Ramana Reddy	Senior Sector Specialist - Energy, KfW
Siddharth Gupta	CEO, L&T Electrolyzers Ltd

Key insights from the roundtable

The participants discussed several issues related to indigenization of the Green Hydrogen value chain, with initial discussions focusing on the realization of demand for green hydrogen. While India is actively pursuing domestic green hydrogen demand, participants noted that it has yet to materialize due to current economic constraints. This lack of demand restricts the economies of scale needed for scaling up manufacturing. Participants emphasized that achieving cost parity for green Hydrogen to global averages remains a critical challenge. Until this milestone is reached, government support in the form of mandates or incentives such as those included in the National Green Hydrogen Mission will be essential.

A key area discussed was India's potential to achieve over 80% indigenization in electrolyser manufacturing. However, developing a competitive manufacturing base would require a resilient supply chain of critical minerals such as Platinum, Iridium, and Nickel, as well as access to critical membrane technologies, for both of which India is dependent on imports.

India's cost competitiveness in the global electrolyser market was also a focus of discussion. Addressing supply chain-related challenges such as availability of key raw materials such as catalyst coatings, and cell frames, and lack of robust vendor base for electrolyser sub-components was identified as a prerequisite for establishing India as a viable exporter. The lack of available land for large-scale green hydrogen production near consumption centres was also mentioned as a factor limiting scalability.

Among potential solutions discussed, participants highlighted that tender document with mandated local procurement quotas or clauses explicitly requiring the manufacture and assembly of electrolyser stacks within India could boost indigenization efforts. The role of multilateral and bilateral partnerships in accessing raw materials and supporting technology development was also discussed, and participants suggested a stronger focus on research and development to indigenize critical components such as membranes, frames, and coatings. Developing scalable proprietary technologies, such as membrane-less electrolysers, was also discussed as a key area for investment in order to drive down costs.

TECHNICAL ROUNDTABLE

FUELLING THE FUTURE: LOCALIZING BIOENERGY SUPPLY CHAINS

Context and rationale

Globally, biofuel demand is projected to grow by **38 billion litres over the next five years,** marking a nearly 30% increase compared to the previous five years. **By 2028, total biofuel consumption is expected to rise by 23% to reach 200 billion litres,** with renewable diesel and biojet fuels contributing nearly half of this growth, while ethanol and biodiesel account for the rest.[158]

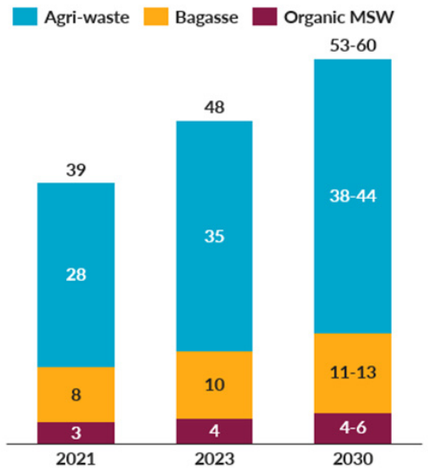
The Bioenergy sector is gaining prominence in **India's efforts towards energy diversification and net zero ambition.** Biofuels and biogas are pivotal components of this sector, offering potential solutions to not only our growing energy demand but also to address challenges such as growing agricultural and organic waste. India is also increasing its global presence in this field through initiatives such as the **Global Biofuels Alliance,** that it played a key role in launching in 2023, which aims to promote the development and adoption of sustainable biofuels and set relevant standards and certification.[159]

The country's vast agricultural expanse results in an abundant supply of biomass, primarily in the form of crop residues and agricultural waste. Of these, the highest share of feedstock is attributed to rice, wheat, sugarcane and cotton. It is estimated that India's overall bio-energy generation potential in 2023 was 48 GWe and could rise to 58 GWe by 2030, with the majority of the potential coming from agri-waste, followed by bagasse[160] and lastly organic MSW.

158.IEA, Report on Transport Biofuels, 2023
159.Ministry of Petroleum & Natural Gas, Official Website

As of March 2023, the cumulative installed capacity of biomass power and cogeneration projects in India reached about 10.2 GW, with Maharashtra and Uttar Pradesh accounting for over 45% of the installed capacity.[161] While 9.8 GW of this is currently driven by co-generation projects, there is strong potential to drive adoption of biomass as a low-carbon fuel for transport and industrial applications and low-carbon energy generation with increased installation of biomass boilers and related infrastructure. Currently, the cement industry for example, has adopted 5-8% biomass substitution as fuel in their boilers,[162] while industries such as paper, have usage rates as high as 45-48%[163] including black liquor. Through demand generation efforts, biofuels adoption could be increased further to support hard-to-abate sectors meet their net-zero commitments.

Figure 22: India's Bio-Energy Generation Potential (GWe)



The country has also made progress across liquid and gaseous forms of bioenergy - from bio-ethanol blending and bio-diesel to biogas and Bio-CNG. India has already achieved 15% ethanol blending in 2024 and is now targeting 20% blending by 2025.[164] The government has targeted 5% biodiesel for use in diesel vehicles by 2030.[165] India has also installed 7 Biogas Generation plants with a combined daily production capacity of about 83,400 cubic meters, and 34 ¬BioCNG Generation plants capable of producing approximately ¬248,000 kgs/per day.[166] Although the progress on compressed biogas has been slower than the planned targets, impeded by cost and infrastructure challenges, some private sector players, which include JBM Group and Torrent Gas are leading the production and adoption of CBG, particularly in hard-to-abate industries. The challenges of high cost of production, limited commercialization of byproducts like bio-fertilizers and high logistics costs due to limited pipeline infrastructure need to be addressed to increase CBG adoption.

This progress across bioenergy and biofuels has been supported by the utilization of existing and effective technologies for combustion, gasification and anaerobic digestion. Some of these technologies, however, pose challenges such as boiler corrosion for industrial applications and indicate a need for further advancements of boiler coatings and newer technologies that are better suited for Indian feedstock (which tends to have higher ash and silica content). The government has rolled out several favourable policies, which include the **National Bioenergy Programme, Sustainable Alternative Towards Affordable Transportation (SATAT),** and the **National Biofuels Policy** among others. Furthermore, The National Biofuels Policy's objective is to reduce the import of petroleum products by fostering domestic biofuel production.

India presents a unique opportunity to drive the indigenization of bio-energy value chains. Despite this, India's domestic capabilities in feedstock processing, biofuel production technologies, equipment manufacturing and deployment for biogas and biofuel plants remain limited. While feedstock sourcing issues are common across all types of fuels, remaining challenges inhibiting bio-energy progress vary by type of fuel produced. Consistent supply of feedstock and sourcing at stable prices pose challenges across all types of feedstocks. Further, the lack of robust supply chain infrastructure limits the sourcing footprint, particularly for crop residue. For organic municipal solid waste, social barriers such as segregation at source pose challenges.

Compressed Biogas (CBG) faces the highest number of challenges beyond poor feedstock management practices, such as, inadequate financing and investment in infrastructure, limited availability of affordable and

160.Dalberg Analysis based on WBA White Paper 2024, FAO and CPCB Data. 2021 MSW Data is based on collections
161.Ministry of New and Renewable Energy, Press Release, 2023
162.WBSCD. 2018.
163.Based on Annual Reports and Sustainability reports of ITC and JK Paper
164.Ministry of Petroleum & Natural Gas, Press Release, 2024
165.IEA, India could triple its biofuel use and accelerate global deployment, 2024
166.World Bioenergy Association, India: The Next Big Bioenergy Revolution, 2024

locally suited technology, and a lack of awareness among producers and consumers. Additionally, CBG systems face challenges in the sale of by-products such as bio-fertilizers due to limited government support and resistance to adoption.

Biomass as a fuel presents a different set of challenges. The absence of advanced technologies for processing and efficient combustion limits the potential for widespread biomass utilization. Torrefaction of biomass in India faces significant challenges beyond feedstock sourcing, including high capital costs for setting up facilities and variability in biomass feedstock quality and supply, which affect efficiency and product consistency. Additionally, the absence of comprehensive policies and financial incentives, coupled with limited awareness and demand for torrefied biomass as a coal substitute, restricts market growth. Addressing these barriers requires targeted financial support, advancements in R&D, and the development of an efficient supply chain.

Bio-ethanol production, while relatively more developed, also faces barriers such as competition for feedstock (e.g., sugarcane and maize) with food production, fluctuating market prices, and limited scalability of second-generation ethanol technologies due to high capital costs and technical constraints.

Addressing these varied challenges will require coordinated efforts between policymakers, industry stakeholders, and research institutions. Targeted interventions to foster innovation, manufacturing capabilities, R&D, and infrastructure development will be essential. This includes specific support for biogas systems and advanced biofuel technologies, such as incentives for waste-to-energy projects, investments in second-generation ethanol plants, and the promotion of decentralized biomass processing units tailored to local contexts.

Potential opportunities and challenges

Some notable **opportunities** for accelerating the indigenization of the bioenergy value chain and improving self-reliance include:

- Potential to generate **53-60 GWe** of energy from biofuels by 2030 across electricity generation, transport and industrial applications
- Investments in localized R&D can drive technological advancements tailored to India's unique needs by promoting rural adoption through decentralized or small-scale biodigesters. India has over **4.31 million family-type biogas plants** as of 2023.[167]
- Potential savings of approximately **USD 4 Bn annually** through oil import reduction via the adoption of bioethanol and biogas by 20305.
- Circular economy potential of utilizing 420-480 MT of waste to generate clean energy and clean fuels by 2030.

However, **several challenges** hinder the progress towards indigenization of bioenergy supply-chains:

- **Ineffective feedstock management** including inefficient collection, aggregation, and storage leading to significant wastage magnified by fragmented supply chains and fluctuating costs
- **Slow adoption of different biofuels** due to lack of organized markets, inadequate infrastructure for production and transportation of produced biofuels indicating a need for demand generation policies, incentives and guidelines
- **High costs of production technologies** and failure to adapt technology to diverse climatic zones and feedstock variations hindering scalability. For instance, higher proportion of rice residue in India with a higher silica and ash content poses challenges for biomass boilers currently available indicating the need to adapt to tropical feedstock and Indian crop mixes.
- **Lack of trained manpower**, especially in rural and remote areas, creating workforce limitations and amplifying production challenges
- **Challenges in securing adequate financing** at feasible cost of capital for larger capacity indicating the need for innovation financing instruments, blended finance and the need to link biofuels production with carbon credits
- **Limited policy support** especially for demand generation and driving adoption of biofuels and prioritizing clean biofuels adoption for hard-to-abate sectors and biomass power generation

Moderators & Participants

IORA Ecological Solutions and the **World Biogas Association** are the knowledge partners for the Bioenergy sector for Bharat Cleantech Manufacturing Platform and Bharat Climate Forum.

167.Ministry of New and Renewable Energy, Official Website

The technical roundtable discussion was co-moderated by **Swapan Mehra, CEO, Iora Ecological Solutions and Dr. D.K. Khare, Senior Advisor, Global Green Growth Institute.**

The participants for the roundtable included:

Roundtable Participants	Title, Organisation
Ambuj Verma	Founder, Unnmukt Solutions
Ashish Kumar	Managing Director, Verbio
Bhagyashri Ghongade	VP Clean Energy, Raj Clean Energy Private limited
Nagendra Kumar	Fellow in the Circular Economy and Waste Management Division, TERI
Sankalp Purwar	Senior Executive, ISMA
Satish Upadhyay	Mission Director, SAMARTH Mission (National Mission on use of Biomass in Thermal Power Plants)

Key insights from the roundtable

During the discussion, participants highlighted several challenges hindering the indigenisation of bioenergy supply chains in India. A significant barrier discussed was the lack of a clear business case for bioenergy projects, compounded by an absence of guaranteed off-takes and diversified revenue streams. Policy limitations also emerged as an area of concern, with participants highlighting the current emphasis on mandates over implementable regulations. The group noted insufficient awareness, knowledge, and skills among farmers and stakeholders, stressing the need for capacity building in bioenergy processes particularly for feedstock management and sourcing.

Infrastructure gaps, particularly inadequate grid and network connectivity, including for Compressed Biogas (CBG) networks, were emphasized as critical bottlenecks. Investment challenges, such as the absence of financial viability guarantees, limited incentives, and inadequate public-private partnerships, were also discussed. Participants underscored the low Technology Readiness Level (TRL) in India compared to other developing nations and the prohibitive costs of advanced bioenergy technologies.

Regional disparities in bioenergy development received attention, as did issues related to feedstock, including the lack of quality analysis before project implementation. Inadequate access to feedstock aggregation equipment and industrial boilers, coupled with limited technical knowledge, further hindered progress. Participants also pointed out the lack of carbon finance mechanisms and the absence of structured models to streamline supply chain logistics, both of which could help leverage agri-residue sequestration potential and enhance bioenergy adoption.

Some measures to address these challenges included strengthening the business case for bioenergy by developing profitable business models, securing guaranteed off-takes, and diversifying revenue streams to monetize the digestate and green attributes as well. Participants advocated for a shift in policy frameworks from mandates to clear, enforceable regulations. Capacity-building initiatives were recommended to enhance awareness and technical skills among farmers and other stakeholders.

To address infrastructure challenges, participants suggested investing in grid and network connectivity, including CBG networks. Promoting indigenous technology development, lowering the cost of advanced bioenergy technologies, and implementing a Hub and Spoke model to centralize processing and streamline feedstock supply were also discussed.

Equitable regional development was highlighted, with a call to promote bioenergy projects in underrepresented areas. Establishing systems for feedstock quality analysis and mandating standardized equipment, along with providing technical training, were seen as critical for success. Participants also recommended integrating carbon finance mechanisms to align bioenergy projects with climate mitigation goals and developing markets for bioenergy-linked carbon credits.

TECHNICAL ROUNDTABLE

ELECTRIFYING BHARAT: THE ROLE OF BATTERY STORAGE IN ACHIEVING NET-ZERO

Context and rationale

Global trends towards decarbonisation are resulting in rapid growth in demand for battery storage. Storage technologies are becoming critical across sectors, especially as a key component in electric vehicles (EVs) and integration of variable renewable energy generation resources. Declining costs have made lithium-ion batteries (LiBs) especially competitive in the market; in 2024 the global LiB prices dropped 20%, reaching a low of USD 115 (approx. ~ INR 9,860) per kilowatt hour (kWh).[168]

As a result, global demand for LiBs is projected to exceed 3.6 terawatt hours (TWh) annually by 2030.[169]

India is well positioned to capture a growing share of the global market, with an expected compound growth rate of 35% over the next decade, according to BNEF projections.[170] Demand growth will be driven by high penetration of EVs, increasing demand of stationary storage applications, and continued growth in the consumer electronics sector. India must act now to promote the indigenization of advanced battery manufacturing market to reduce reliance on importations and compete with an uptick in global policy supporting domestic battery manufacturing in China, Europe, Southeast Asia, and the United States.

168.Catsaros, Oktavia, "Lithium-Ion Battery Pack Prices See Largest Drop Since 2018," BloombergNEF, December, 2024
169.Leach, Andy, Lithium-Ion Batteries: State of the Industry 2023, BloombergNEF (BNEF), December 2023
170.Ibid

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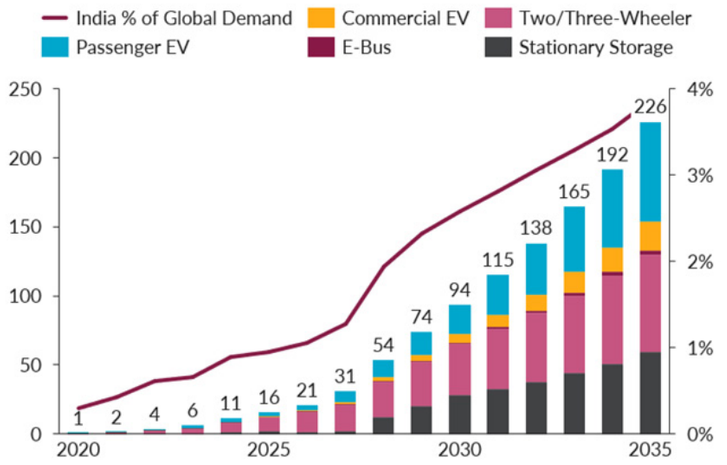
Figure 23: India Battery Demand Outlook : Annual battery demand (GWh)



India's energy requirement is projected to reach nearly 2,474 TWh by FY 2031-32, an increase of more than 79% from FY 2021-22; while peak demand is anticipated to exceed at 458 GW in FY 2031-32.[171,172] Over 53% of installed generation capacity is expected to be variable renewable energy (VRE) sources like solar and wind. Battery energy stationary storage (BESS) technologies are critical for enabling the integration of high volumes of VRE generation, as well as other distributed energy resources. Projections within India estimate approximately 42 GW (208 GWh) of BESS will be required to integrate 392 GW of VRE by 2030.[173]

Currently, India has a negligible presence in the global supply chain for manufacturing of advanced cell technologies. To meet battery demand from all segments, India will require 5 gigafactories with nameplate capacity of 10 GWh of annual production in 2025, growing to 26 gigafactories by 2030.[174] In May 2021, the Government of India announced the National Programme on Advanced Chemistry Cell Battery Storage, a USD 2.1 Bn (INR 18,100 crore) PLI scheme that aims to attract global investments to establish battery gigafactories in India. Under the NPACC, the selected bidders will set up manufacturing facilities with the goal of 50 GWh of domestic capacity by 2030.[175] 10 bids representing 128 GWh of manufacturing capacity were received, and the initial recipients were announced in July 2022.[176] Beyond the PLI, policies and investments that induce India-based manufacturing to meet domestic demand can help the country create jobs and capture economic value from this sunrise sector, while reducing dependence on imports to meet the future an advanced energy economy demands.

India has the resources and expertise to build battery cells and is already building the battery packs. However, the value contributions are sensitive to raw material prices. For example, the value of cathode is higher in NMC batteries as compared to LFP batteries due high global prices of nickel, manganese and cobalt.[177] The spike in raw material costs leads to higher battery costs which can impact the economics of end-use applications. Hence battery chemistries that rely on indigenous raw materials allows maximum domestic value capture and are also better insulated from any future supply or cost shocks.

The scarcity of domestic reserves of minerals such as lithium, cobalt, nickel, and graphite warrants the need for developing other emerging technologies for India. Efforts to develop domestic cell manufacturing capacity will require heavy investments in innovative technologies that capitalize on resources abundant in India. These innovative chemistries include sodium-ion, aluminum air, liquid metals, and zinc hybrid. It is also important for the cell and pack manufacturers to understand the specific needs of their market and adapt, as global technology and applications change over time, and moves in the direction of higher performing and lower cost advanced batteries. Using the technology performance metrics such as discharge duration, cycle life, and energy density allows for market forces to determine the minimum threshold of battery performance required to meet domestic demand and also compete in global markets.

With the cost of batteries falling, many end-use applications are increasingly becoming economically viable. Others are on the cusp of monetization, such as long duration energy storage, which is a critical component of energy storage roadmaps in international

171.Government of India, Ministry of Power, Report on the Twentieth Electric Power Survey of India (Volume-I)
172.The Hindu Business Line, Govt revises India's peak power demand upwards to 458 GW by 2032
173.Government of India, Ministry of Power Report on Optimal Generation Mix 2030 Version 2.0
174.NITI Aayog, RMI, and RMI India, Need for Advanced Cell Energy Storage in India (Part I of III), pg. 29, February 2022.
175.Ministry of Heavy Industries, GoI, "PLI Scheme for National Programme on Advanced Chemistry Cell (ACC) Battery Storage,"
176."Three Companies signed Program Agreement under (PLI) Scheme for Advanced Chemistry Cell (ACC) Battery Storage," Ministry of Heavy Industries, Press Information Bureau, Government of India, July 2022
177.NITI Aayog, RMI, and RMI India, Need for Advanced Chemistry Cell Energy Storage in India (Part II of III), pg. 41, April 2022

markets. The trend of economic viability will only accelerate as battery performance is continuously improving in tandem with the price decline. Battery manufacturing presents an opportunity to partake and become a leader in a global sunrise industry and accelerate indigenisation of the energy and transport value chain. India has a window of opportunity to capture a large market share of electric mobility and the batteries required to support it. The success will require a strong co-ordinated strategy to overcome its relatively nascent position in advanced cell manufacturing supply chain.

Potential opportunities and challenges

- The annual market for stationary and mobile batteries in India could range between USD 6-15 Bn by 2030, with almost 80% from cells and 20% from pack assembly and integration. and will be dependent on chemistry.[178] India could capture up to 90% of LFP and 43% of NMC potential through indigenisation of the value chain from material processing up to pack assembly and integration.[179] Other chemistries such as sodium-ion could see nearly 100% of value captured in India with a supportive local supply chain.
- Successful indigenisation of battery manufacturing and establishing of India as a global leader in the energy storage technology market and could be achieved by embracing circular economy principles within the battery manufacturing space. Globally, moving from a linear to circular economic model for could result in a reduction of 34 Mt in GHG emissions while creating an additional economic value of approximately USD 35 Bn.[180]
- Potential the direct job creation potential of battery plants to be around 90 to 180 jobs per GWh/y production by 2030 in India (based on EU projections), with additional indirect jobs expected across the battery value chain.[181]

The challenges to addressing these opportunities exist across multiple areas:

- **Raw material sourcing** presents a significant barrier to capturing a large portion of the battery manufacturing value chain. India currently has extremely low reserves of in-house ingredients such as lithium, cobalt, and battery-grade graphite. These key components in current advanced battery chemistries make India reliant on the Chinese market for imports. New infrastructure for advanced metal processing and refining machinery to process the raw material procured could help have the right concentration of different materials used.
- **R&D to identify the kind of 'battery technology' that is ideally suited for Indian market** and in turn, establish its entire supply chain in the country becomes a key investment decision. The battery market is evolving as battery chemistries see continued advancements in material science. Globally, several variants of LiB NMC are being developed to reduce the proportion of cobalt. R&D exists to explore potential savings realized using silicon as anode instead of graphite. Increased R&D investments in India are imperative to adopt and develop similar technologies
- **Lack of appropriate information exchange** due to technology patents is a key concern, limiting the technical expertise gained at local levels. Technology transfer, including know-hows of advanced cell chemistries, development of alternatives, and ongoing R&D in material science.
- **Lack of technical expertise and knowledge pertaining** to the sector, especially when it comes to hiring skilled labour for plant operations and maintenance is an operational risk.
- **Capital expense is also a significant barrier** for market entrants. Larger cell manufacturing facilities demand high up-front funding. Recent projects with more than eight gigawatt-hours per year have invested on average about USD 120 Mn per gigawatt-hour per year in capacity. Approximately 74% of this funding is for necessary equipment.[182,183]
- **Financial institutions may be reluctant to provide loans for a new technology** due to lack of technical expertise and uncertainty or security-related concerns when it comes to resale value and perceived lack of assured off-take or a guaranteed market. Banks may charge a higher rate of interest for a comparatively newer technology to minimize risk at their own end, which will be especially prominent for innovative technologies seeking to meet emerging end uses, such as long duration storage.

Moderator & Participants

Rocky Mountain Institute (RMI) and the **India Energy Storage Alliance (IESA)** are the knowledge partners for the BESS sector for Bharat Cleantech Manufacturing Platform and Bharat Climate Forum.

The technical roundtable discussion was moderated by **Jagabanta Ningthoujam, Principal, RMI.**

The participants for the roundtable included:

Roundtable Participants	Title, Organisation
Abhijeet Chatterjee	VP, Hitachi India
Akshay Jain	Founder, Cancrie
Nishant Idnani	Managing Director, Vaultus Green Funding
Puja Jain	Co-Founder, ElementRE
Ravi Bharioke	Co-Founder, Enerjazz
Sriram Ramakrishna	Business Head - Energy Systems, Reliance New Energy
Umang Maheshwari	Director, Solutions Deployment, GEAPP

Key insights from the roundtable

The roundtable discussions highlighted several challenges to advancing India's battery ecosystem, with participants emphasising the significant reliance on imports for key raw materials like Lithium, Cobalt, and Nickel, exposing supply chains to vulnerabilities in stability and cost. The lack of domestic supply, insufficient international partnerships, and limited processing and refining capacities were identified as key gaps. While indigenization of cell manufacturing is expected to improve, complete indigenization efforts remain incomplete, with pack assembly existing for EVs, but proving insufficient for grid-scale systems. System integration processes, including energy management systems (EMS) and cybersecurity, also heavily depend on non-Indian partners.

Another pressing issue discussed was India's limited advanced manufacturing capacity, with an estimated need for 26 gigafactories by 2030 to meet demand. Participants noted that stationary storage is gaining global interest due to cost reductions, opening up new applications. However, India is lagging behind key international players by about five years. Scaling up production at competitive volumes while ensuring profitability was highlighted as a challenge, especially without control over the entire supply chain. Uncertainty in long-term planning, including transportation strategies and utility frameworks, was cited as a risk for businesses seeking financial stability and market opportunities.

Additionally, insufficient investment in advanced battery R&D was highlighted as a significant hurdle. Deep-tech startups, while capable of improving efficiencies, face long investment timelines of 7–8 years from initial R&D grants to funding from financial institutions. A funding gap was noted between government R&D grants in the initial 2-3 years and venture capital readiness.

Participants also discussed the absence of a robust recycling and circularity infrastructure, which limits material recovery and sustainability. Second-life applications for batteries, such as those between EV usage and recycling, were noted as overlooked opportunities, with government support through measures such as quality certifications for second-life applications suggested to promote this.

Solutions discussed at the roundtable included establishing a unified government mission to indigenize the entire battery supply chain, encompassing raw material investments, processing and refining capacities, cell manufacturing, pack assembly, system integration, and circularity. Participants emphasized the need for improved long-term planning with clear five-year duty horizons to enable business and financial stability.

Quality assurance measures were recommended to safeguard against low-quality imported materials that pose safety risks and threaten the nascent industry. Demand creation was another area of focus, with suggestions to update power market designs for better value monetization of Battery Energy Storage Systems (BESS), ways to transition C&I customers from captive thermal plants to renewable energy and BESS, and to explore nascent applications, such as replacing diesel generators with battery storage and enhancing grid flexibility through smart charging.

Advancing R&D in alternative chemistries and materials, such as Sodium-ion and Aluminium-air batteries, was strongly advocated. These technologies, leveraging India's abundant resources, could reduce dependence on imports. Participants also called for improving funding potential for Indian BESS startups through blended finance instruments, government initiatives like dedicated accelerator programs and others. Developing domestic recycling ecosystems was another recommendation, with the implementation of a nationwide Extended Producer Responsibility (EPR) framework and the creation of forums for startups to engage in second-life applications. Establishing quality standards for second-life products was highlighted as a critical enabler.

Finally, participants stressed the importance of facilitating technology transfers through international collaborations and patent-sharing agreements with like-minded partners to address gaps in local expertise and advanced production techniques.

178.Ibid, pg. 39
179.Ibid, pg. 41-42
180.Reuse and Recycling: Environmental Sustainability of Lithium-Ion Battery Energy Storage Systems, Energy Sector Management Assistance Program (ESMAP), The World Bank, pg. 11
181.M. Steen et al., EU Competitiveness in Advanced Li-ion Batteries for E-Mobility and Stationary Storage Applications – Opportunities and Actions, European Commission, pg. 24, 2017
182.James Eddy, Alexander Pfeiffer, and Jasper van de Staaij, "Recharging economies: The EV-battery manufacturing outlook for Europe," McKinsey and Company, pg. 6, June 2019
183.Based on values from BloombergNEF's Bottom-up Battery Cost Model, March 2021

TECHNICAL ROUNDTABLE

ROLE OF NBFCs IN SUPPORTING CLEAN TECHNOLOGIES

Context and rationale

Non-Banking Financial Companies (NBFCs) have traditionally played a critical role in last-mile credit delivery to the unserved or underserved sectors and individuals in India, ensuring credit flow to sectors that banks are unable or unsuited to serve. Lighter regulations, deeper geographical reach, closer customer connect, and nimble operating models have ensured that NBFCs are often the first port of call for New-To-Credit clients. While the total loan portfolio size of NBFCs (USD 480 Bn (INR 40 lakh crore) as of March 2024), may pale in comparison to that of Banks (USD 2 Tn (INR 170 lakh crore) as of March 2024), the picture is quite different in segments where NBFCs operate. For instance, credit growth by NBFCs to the MSME sector was more than three times that of banks, benefiting from their ability to offer customized financing solutions.[184]

Cleantech equipment manufacturers as well as end-consumers face a significant credit gap, owing to factors like untested technology, unstable business models, unfamiliarity with equipment use-cases and resale values leading to unproven economic viability. In this context, NBFCs, which are known for simpler documentation requirements (relative to Banks), faster turnaround times, more flexible repayment structures, and cashflow-based lending (as against collateral-based), can use their strengths and unique positioning in playing a pivotal role in supporting cleantech manufacturing and adoption, thereby helping bridge some of this credit gap.

Within cleantech, predictably, NBFCs have been so far most active in clean energy and electric mobility sectors. NBFCs like Tata Cleantech Capital (now Tata Capital) have played an important role in lending to cleantech, primarily renewable energy. Newer entities like Mufin, Revfin, Ecofy and others are supporting the mobility transition, with NBFCs also active in financing EV charging infrastructure as well as battery swapping facilities, in part encouraged by initiatives like SIDBI's 50KEV4ECO and EV-RSF.

Emerging segments such as energy storage, energy efficiency, water efficiency, bioenergy and waste-to-energy, and Agritech are other segments where NBFCs are increasingly getting active. NBFCs provide both project financing as well as working capital, with their target borrower set cutting across Developers, Asset Owners, Original Equipment Manufacturers, System Integrators as well as end consumers in these sectors. This includes financing for solar powered agri-machinery, solar coolers, precision agri-equipment and other sustainable farming inputs. Additionally, distributed on-farm biomass plants are increasingly seen as more viable, making them more suitable to NBFCs, and various pockets of opportunities expected in the waste management sector as well. Caspian's loan product, launched in partnership with MFIs and technology providers, for irrigation systems and other sustainable farming solutions is a case in point.

Looking ahead, NBFCs could play a key role in designing innovative financial products and instruments with features such as risk sharing, guarantees, pooled bonds, results-based-financing, among others, in conjunction with institutions such as DFIs. Such instruments can add to the strengths NBFCs already have in bridging the credit gap and accelerate the development of cleantech manufacturing in India.

Potential opportunities and challenges

The opportunities for NBFCs to support cleantech manufacturing and value chains in India include:

- NBFC is well-suited to address the funding gap for cleantech manufacturing and adoption. For instance, NBFC is better suited to meet financing demands for start-ups looking for debt, small-scale and distributed cleantech solutions and their adoption
- Lending to cleantech MSMEs in bioenergy, solar, wind and charging infrastructure could be addressed by NBFCs as NBFCs reported more than 3x growth in MSME lending in FY23 y-o-y compared to both Public Sector Banks and Private Sector Banks[185]
- Rapidly evolving nature of cleantech, requiring nimble and flexible financing structures, making NBFCs better suited to meet the financing needs
- Tapping into growing pool of thematic capital

The challenges to addressing these opportunities exist across multiple areas:

- Limited availability of affordable capital for the NBFCs, making the final cost of delivered credit to the end-clients also relatively high
- Limited risk appetite and lack of technical knowledge (which is required to assess techno-commercial feasibility of several new technologies)
- Uncertainty on which technologies to support, owing to both obsolescence risk as well as risk of policy change
- Early stage in the life cycle of the business, in the case of several startups, making them unsuitable and not ready for debt capital
- Regulatory and compliance constraints, for instance, limitations on providing revolving credit
- Underdeveloped ecosystem for blended finance

Moderators & Participants

Climate Policy Initiative (CPI) and **Finance Industry Development Council (FIDC)** are the knowledge partners for NBFCs for Bharat Cleantech Manufacturing Platform and Bharat Climate Forum.

The technical roundtable discussion was co-moderated

184.RBI Report on Trend and Progress of Banking in India, December 2023

185.CARE Ratings research report, June 2024

by **Vivek Sen, India Director, Climate Policy Initiative (CPI) and Raman Aggarwal, Director (& Former Chairman), Finance Industry Development Council.**

The participants for the roundtable included:

Roundtable Participants	Title, Organisation
Bonani Roychoudhury	Managing Director, NABSam-ruddhi Finance
Neelam Pandita	AVP – ESG and CSR, Blacksoil Capital
Nishant Idnani	Managing Director, Vaultus Green Funding
Prakash Kumar	Deputy Managing Director, SIDBI
Sai Pramodh	Associate Vice President, Caspian
Sandeep Bhattacharya	Advisor- Climate Change, GIZ GmbH
Siddharth Ray	Northern Arc
Vivekanandhan Thirunavuk-karasu	Lead of ESG, Sammunnati
Vivek Jain	CBO, Stride Green

Key insights from the roundtable

India is the 3rd largest NBFC market globally and could play a pivotal role in cleantech manufacturing and adoption. Participants recognized NBFCs as first movers and risk-takers in financing green technologies, citing examples such as CNG and EV financing. Some emerging areas highlighted during the discussion included sustainable agriculture, waste-to-energy projects, biofuels, and cooling technologies, with solar energy continuing to be a key focus.

Among the key issues raised by the participants were challenges in passing benefits to end users due to a lack of incentives for financiers, despite issuing green bonds. They also emphasized the importance of identifying innovative startups in clean and climate tech to enhance portfolio diversity, while highlighting the potential role of intermediaries in managing assets and enabling refinancing.

The discussion also underscored the need for Government support and specialized schemes targeting small and niche NBFCs. Participants suggested that while the Government was supporting the manufacturing sector through initiatives like the PLI schemes, the NBFC sector also needed a special financing scheme due to the large risks taken by financiers particularly in the cleantech sector.

Another area discussed was the role of risk-sharing facilities, such as those facilitated by multilateral organizations like the World Bank, to provide guarantee coverage for NBFCs operating in innovative green technology sectors. Participants emphasized the importance of schematic interventions through international funds, including the Green Climate Fund (GCF), to enhance green financing capacity. The creation of refinancing markets, particularly for sectors like EVs, was highlighted as essential for efficient capital deployment.

Financial behaviour, participants noted, is strongly influenced by policies; hence participants also discussed the importance of statutory provisions to secure financiers' rights over assets, drawing comparisons to the success of vehicle financing under the Motor Vehicles Act. The need for collaboration among OEMs, financiers, and policymakers was stressed to address evolving technological and financial risks, particularly issues related to valuation of assets based on emerging technologies. In this regard, the concept of 'pay-as-you-go' financing models was highlighted, based on the cashflows from the asset rather than the value of the asset, as a way to extend financing to larger numbers of customers, especially MSMEs.

Partnerships with NBFCs were noted as a way to channel government schemes, such as interest subsidies under the GIFT scheme, to benefit end users. The use of co-lending was also suggested as a way to address some of the issues related to risk and capital. Participants also highlighted the importance of addressing demand-side issues, such as awareness gaps among panchayat-level stakeholders, to drive green financing for initiatives like e-rickshaws and solar rooftops.

TECHNICAL ROUNDTABLE

GLOBAL TRADE AND CLIMATE DYNAMICS: IMPACT AND ROLE OF GREEN TARIFFS, NEARSHORING, DOMESTIC REGIME AND OTHER TRADE SHIFTS ON CLEANTECH MANUFACTURING AND GREEN ENERGY

Context and rationale

Over the past ten years, worldwide commerce in cleantech and climate-tech products has grown rapidly. The International Energy Agency (IEA) estimates that in order to achieve net-zero goals by 2030, expenditures in clean energy must triple. With rising global tendency towards cleaner energy sources along with strong domestic demands, India's cleantech manufacturing sector has the potential for substantial growth, with an estimated domestic market size of USD 120-150 Bn by 2030.[186]

India is implementing domestic measures to boost clean technology manufacturing, such as the Production-Linked Incentive (PLI) Scheme, National Green Hydrogen Mission, and Atmanirbhar Bharat initiative, which aim to reduce import dependency and promote domestic manufacturing of cleantech. These efforts, combined with ambitious non-fossil energy installed capacity targets of 500 GW by 2030[187] and growing cleantech start-ups, position India as a key player in the global clean technology sector.

While India has several advantages in cleantech manufacturing which needs to be leveraged for maximizing the manufacturing opportunities, global trade policies also have an impact on India's cleantech sector. Global trade policies are increasingly incorporating sustainability measures that influence the competitiveness of cleantech across countries. Some noteworthy examples of mechanisms which incentivize greener production include the EU Carbon Border Adjustment Mechanism (CBAM) and the US Inflation Reduction Act (IRA).[188] While CBAM poses compliance costs and market access challenges for Indian exporters, it might encourage investment in cleantech to reduce carbon emissions. Furthermore,

186.Dalberg's analysis
187.Ministry of power, 500 GW Non-fossil Fuel Target | Government of India
188.The Trump Administration has issued an Executive Order to repeal the IRA

sustainability standards and certifications required by importing nations can also act as non-tariff barriers for Indian exporters. Deliberating over India's strategic response to these evolving global norms is critical to ensuring that India's cleantech sector remains competitive in global markets.

Furthermore, disruptions in global supply chains due to events like COVID-19 pandemic, geopolitical tensions and unilateral trade-related environmental measures have also led to increasing trends of nearshoring arrangements. As companies nearshore operations to regions with greener technology infrastructure, they bring along more sustainable practices and innovations. Nearshoring often involves setting up operations in countries with strong green investment incentives or government-backed renewable energy initiatives. For instance, countries like Vietnam and Mexico are attracting green investments in solar and wind energy projects, which can support the sustainable development of nearby manufacturing hubs. This highlights the need for India to not only strengthen its domestic cleantech manufacturing capacity but also to implement robust incentives and policies that can attract investment, foster innovation, and position the country as a competitive player in the global green economy.

Despite India's accomplishments in cleantech sector, challenges remain. For instance, India depends heavily on imports of lithium, cobalt, and rare earth elements required for batteries and EVs, exposing it to supply chain vulnerabilities. There is also a need for imports of crucial components like polysilicon and wafers, weakening cost competitiveness and restraining the local value addition potential. Furthermore, India faces stiff competition from China in cost and production efficiency. Although India has been increasing its production capabilities, the domestic supply chains for cleantech manufacturing are underdeveloped.

To capitalize on its potential to emerge as a leading player in cleantech manufacturing and establish itself as a global hub for cleantech exports, India needs to strategically leverage partnerships with countries having advanced cleantech sectors, such as Switzerland. India already has collaborations with the EU, including the Clean Energy and Climate Partnership and European Hydrogen Week, as well as bilateral partnerships with EU Member States like Denmark under the Green Strategic Partnership, and the US. India should build upon these existing alliances to strengthen its green hydrogen capabilities, enhance technological expertise, attract investments in cleantech sectors, and expand into emerging areas such as electric mobility and smart grid technologies.

Addressing the challenges related to global trade policies, sustainability standards, and domestic constraints is essential for India to unlock its export potential and drive economic growth. Strategic global partnerships and proactive engagement in shaping international policies will be key to ensuring that India's cleantech sector thrives in an increasingly competitive global landscape. Forums such as the BRICS, the G20, and bilateral agreements can be utilized to advocate for technology transfer and establishment of funding mechanisms and capacity-building initiatives to support cleantech adoption and trade.

Potential opportunities and challenges

By carefully exploring a combination of incentives, tariff adjustments, and global partnerships, India will have opportunities to foster a robust domestic manufacturing ecosystem while ensuring competitiveness in global markets

- **Enhancing cost competitiveness:** Tariff reductions on raw materials and bilateral trade agreements with countries like Australia, Chile, and Indonesia can potentially help lower production costs and secure long-term access to essential minerals.
- **Facilitating technology transfer and joint ventures:** Lowering tariffs on advanced cleantech equipment can facilitate technology transfer and joint ventures by reducing costs for foreign collaboration, enabling access to cutting-edge technologies, and fostering local manufacturing capabilities. Key focus areas include battery cell and pack technology, efficient solar modules and PV cells, EV motor and powertrain designs, fuel cells, hydrogen combustion engines, and high-efficiency electrolysers for hydrogen production.
- **Expanding global export potential:** Expanded trade partnerships through Free Trade Agreements (FTAs) with EU/ US with a focus on ensuring zero-tariff access for Indian solar panels, wind turbines, and electric vehicles could further elevate the potential export opportunity for cleantech manufacturing to USD 40-45 Bn annually by 2030, assuming 10% global export share.[189]
- **Strengthening India's role in global supply chains:** Special Economic Zones (SEZs) dedicated to cleantech manufacturing with potential benefits such as tax holidays and duty-free imports of components could help India to become a key node in the global cleantech supply chain, especially in the area of wind turbine, solar modules PV, and semiconductor.

189.Dalberg's analysis

Bharat Climate Forum 2025

The challenges to addressing these opportunities exist across multiple areas:

- **Geopolitical risks:** Trade wars, geopolitical tensions, and protectionist policies among major economies (e.g., US-China) could indirectly impact India's access to key markets.
- **Proximity advantage of global competitors:** With the increasing preference for nearshoring, countries near large markets (e.g., Mexico for the US, Vietnam for China, Turkey for EU) may have a logistical and cost advantage over India due to shorter supply chains.
- **Technological and innovation gap:** Limited investment in innovation can restrict the development of globally competitive, high-value products.
- **Lack of sufficient domestic certification agencies:** This leads to increased lead time and costs, delaying the market entry for manufacturers exporting indigenized products, thus, hindering competitiveness in both domestic and international markets.

Moderator & Participants

Centre for WTO Studies, Indian Institute of Foreign Trade (IIFT) is the knowledge partner for Global Trade for Bharat Cleantech Manufacturing Platform and Bharat Climate Forum.

The technical roundtable discussion was moderated by **Dr. Pritam Banerjee Professor & Head, Centre for WTO Studies Indian Institute of Foreign Trade.**

The participants for the roundtable included:

Roundtable Participants	Title, Organisation
Ajay Srivasatava	Global Trade Research Initiative (GTRI)
Ambuj Verma	Unnmukt Solutions
Arjun Goswami	Cyril Amarchand Mangaldas (CAM)
Atul Sharma	Sarvada Legal, Delhi
Puja Jain	Co-Founder, ElementRE
Vivek Srivastava	CEO, India Business Suzlon Energy

Key insights from the roundtable

During the discussion, participants highlighted critical considerations for the survival of domestic manufacturing in the green technology sector, namely ensuring anchored demand to drive development of the entire value chain, implementing tariff measures, and adopting structural non-tariff measures.

Participants explored the role of Government interventions such as PLI in bringing investment and technology to India. They noted that several Indian manufacturers were only assembling intermediate components in India, including for products that were exported, and suggested that significant government support and protection would be needed develop the entire value chain. Participants noted that without a reasonable certainty of demand, private players were hesitant to make significant investments in emerging technologies, and emphasised the need to have large firms act as demand anchors to generate scale in these sectors.

On the issue of protection, participants discussed global examples of structural and tariff barriers used to protect domestic economies and suggested that any new policy measures would need to incorporate these to be effective. Participants also emphasized that while subsidy support such as PLI would not be viable in the long term, and that private players needed to develop cost competitiveness, many current leading global manufacturers benefited from initial strategic support and backing by their government.

They also suggested that both the Government and industry needed to prioritise areas and sectors for intervention and investment, mentioning that building domestic capacity in certain sub-segments like micro-motors would be unviable considering the significant advantages held by leading global manufacturers.

Geopolitical issues were also discussed, with participants highlighting the reliance on international supply chains for components like Polysilicon and Lithium, including over-dependence on single markets. The vulnerability of the supply of such components as well as the availability of technology to produce and refine them, were noted as bottlenecks. Participants called for India to have a micro level study of each stage of the supply chain, combining domestic capacity building with targeted international partnerships for both materials and technology.

Participants also debated about balancing principles of free trade with protecting national interests. They pointed to global examples of protectionism by leading developed nations and noted the need for government intervention and tariffs to ensure India's economic development.

Finally, participants touched on India's energy transition and emphasized the importance of layering the understanding of green transition with considerations of energy security and energy independence to ensure a holistic approach to achieving sustainability goals.

TECHNICAL ROUNDTABLE

MOBILIZING INVESTMENTS AND FINANCING FOR CLEANTECH MANUFACTURING IN INDIA: WHAT IS THE ROLE OF DEVELOPMENT FINANCE?

Context and rationale

Globally, cleantech supply chain investments stood at USD 200 Bn in 2023, growing more than 70% compared to 2022,[190] accounting for around 0.7% of global investment across all sectors and driving more spending than established industries like steel.[191] 90% of investment was directed towards solar PV and battery manufacturing with high concentration in manufacturing capability with little diversification by 2030.[192] These investments are fairly concentrated in a few geographies with most clean energy manufacturing investments concentrated in China, followed by the United States and the European Union. Notably, Asian countries other than China received only 4% of investments in 23-24.[193] The funding is skewed towards debt, exacerbated by a drop in equity funding for the two years in a row. Within the pool of climate tech equity investments in 2023, China led with USD 25 Bn, followed by US, EU and then India with USD 4.3 Bn.

India aims to transition to a low-carbon economy by achieving 500 GW of non-fossil energy installed capacity and reducing carbon intensity by 45% (compared to 2005 levels) by 2030. Cleantech manufacturing will play a key role in this transition as well as enable economic competitiveness, resilience and security. Achieving scale in cleantech manufacturing requires substantial capital, advanced technology, and robust market mechanisms. According to multiple estimates, India needs USD 7.2 -12.1 Tn to achieve the transition by 2050.[194] India will need an annual investment of USD 120-140 Bn in clean energy by 2030,[195] with the Reserve Bank of India suggesting green finance should account for at least 2.5%—3.5% of GDP annually until 2030.[196]

Financing from domestic and international sources is crucial, with India's current investments in climate tech at just 1.5% of its GDP. Factors influencing investment decisions extend beyond manufacturing costs and include the size of domestic markets, skilled labour availability, infrastructure readiness, permitting processes, and proximity to customers.[197] While India has substantial investment in renewable energy generation, share of manufacturing is significantly smaller. Funding for cleantech in India increased after a slow first-half of the year, ending the third quarter of 2024 at USD 2.4 Bn from 29 deals. Notable deals were initial public offerings (IPO) by electric-scooter and bike maker Ola Electric Mobility (USD 734 Mn) and solar companies Premier Energies (USD 338 Mn), Ganesh Green Bharat (USD 15 Mn), and Sahaj Solar (USD 6.3 Mn).[198]

While Green FDI, which encompasses investments aimed at environmental sustainability, constitutes approximately 3% of India's total FDI inflows in 2020, India's green financing landscape is predominantly supported by domestic capital, primarily domestic debt.[199] In 2022, around 83% of India's tracked green finance for mitigation was sourced domestically, with the private sector contributing 66% of domestic mitigation finance.[200]

Cleantech financing in India faces significant challenges due to systemic and sector-specific factors. The risk-return mismatch for equity investors, due to lower margins and longer time horizons, is a major hurdle. Accessing debt finance is also a challenge, as banks and NBFCs prefer short-term, low-risk projects over capital-intensive cleantech ventures that require high upfront costs and long payback periods. Additionally, India's high capital costs, with borrowing rates ranging from 8-20%, make domestic cleantech projects less competitive globally compared to developed economies with rates of 2-5%. Early and growth-stage cleantech companies face challenges in securing equity participation due to perceived uncertainty around their profit margins. Investors are reluctant to back ventures with uncertain financial returns, which hampers the growth of promising startups. Furthermore, the lack of cohesive green financing policies, tax incentives, and long-tenor green bonds in emerging sectors like green hydrogen and bioenergy limits the flow of affordable capital. In this context, Development Finance Institutions and Investments could play an instrumental role in bridging the funding gap for 2030, mitigating investment risks, and enabling technology transfer.

To address the challenges in cleantech financing in India, it is essential to focus on improving the risk-return profile for investors, promoting long-term debt financing, and lowering capital costs through government-backed schemes and favourable policies. Supportive government policies such as the Production-Linked Incentive (PLI) schemes and initiatives like Make in India and Atmanirbhar Bharat, have the potential to accelerate domestic and foreign investments across cleantech manufacturing sectors. Increasing equity participation could be encouraged through tax incentives and dedicated cleantech investment funds, while enhancing policy and regulatory support, such as cohesive green financing policies and long-tenor green bonds, could help reduce barriers to funding. Leveraging development finance could not only help derisk the investment but also strengthen the ecosystem with technical assistance. Solving these challenges is crucial for unlocking investment in the sector, enabling cleantech companies to scale, and accelerating India's transition to a sustainable, competitive green economy.

Potential opportunities and challenges

The opportunities for driving financing for cleantech manufacturing in India and improving self-reliance include:

- **Growing Market Potential:** The renewable energy and e-mobility sectors are projected to generate an annual market of USD 120–150 Bn by 2030, driven

190.IEA, Advancing Clean Technology Manufacturing, An Energy Technology Perspectives Special Report by International Energy Agency, 2024
191.Ibid
192.Ibid
193.Bloomberg NEF, Energy Transition Investment trend, 2024
194.Economist Impact, Scaling clean energy: financing and transition strategies for India's sustainable future, 2024
195.Economist Impact, Scaling clean energy: financing and transition strategies for India's sustainable future, 2024
196.Economist Impact, Scaling clean energy: financing and transition strategies for India's sustainable future, 2024; McKinsey, Decarbonizing India report, 2022
197.IEA, Advancing Clean Technology Manufacturing, An Energy Technology Perspectives Special Report by International Energy Agency, 2024
198.Bloomberg NEF, Investment Radar Q3 2024
199.Climate Policy Initiative, Landscape of Green Finance in India 2022 Full Report, 2022
200.Climate Policy Initiative, Landscape of Green Finance in India 2024 Full Report, 2024

by increasing energy demands and a shift towards sustainable transportation.

- **Bridging the Energy Transition Financing Gap:** To meet energy transition goals, India needs to address a financing gap of USD 260–270 Bn by 2030, highlighting the opportunity for substantial investment in clean energy infrastructure.[201]
- **Export Opportunities:** India can focus on capitalizing on the global demand for clean energy technologies with a potential export opportunity of USD 40-45 Bn annually by 2030, assuming 10% global export share.[202]

The challenges to addressing these opportunities exist across multiple areas:

- **High Financing Costs for Emerging Technologies:** The borrowing costs as well as the cost of equity capital are higher compared to leading global economies
- **Low-Risk Appetite Among Financiers:** Financing is readily available for established technologies, but emerging cleantech sectors struggle to attract funding due to perceived high risks. Debt financing for cleantech ventures remains limited, as banks and NBFCs favour short-term, low-risk projects
- **Limited Long-Term Financing Instruments:** India's capital markets lack sufficient long-duration investment options, such as AAA-rated bonds with tenures beyond ten years, hindering the attraction of patient capital required for large-scale manufacturing investments.
- **Policy and Regulatory Gaps:** Emerging cleantech sectors like green hydrogen and bioenergy face regulatory gaps, with insufficient green financing policies and tax incentives, restricting the flow of capital.
- **Absence of Robust Climate-Risk Investment Regulations:** Indian financial institutions lack clear guidelines, taxonomy or mandates on allocating capital to sustainable projects, unlike developed economies, although initial directions have been issued by SEBI and RBI on climate risk disclosures.
- **Lack of Foreign Direct Investment (FDI):** India's green financing landscape is predominantly supported by domestic capital, with FDI playing a relatively minor role. This limits the influx of international funding and expertise needed to scale the sector.
- **Fragmented Multilateral Development Bank (MDB) Funding:** MDBs focus on small pilot projects, and domestic DFIs need to aggregate smaller opportunities into larger investable pipelines to attract more substantial MDB capital.

Moderators & Participants

Invest India and the **World Bank** are the knowledge partners for Financing for Bharat Cleantech Manufacturing Platform and Bharat Climate Forum.

The technical roundtable discussion was co-moderated by **Sujatha UG, Vice President - Global Partnerships & Net Zero, Invest India and Amit Jain, Senior Energy Specialist, World Bank.**

The participants for the roundtable included:

Roundtable Participants	Title, Organisation
Aadil Chitalwala	Vice President, PEAK Sustainability Ventures
Akshay Gupta	Managing Partner, Econ Climate Fund
Ashish Agrawal	Director, Resurgent India Ltd
Divyam Nagpal	Principal Specialist, Renewable Energy, SEforAll
Nehal Gupta	Founder and MD, AMU Leasing
Rohan Ghalla	CEO, Spectrum Impact
Sarthak Rastogi	Associate VP, Huddle Ventures

Key insights from the roundtable

Among the key challenges discussed during the roundtable were limited access to long-term capital, limited role of development finance institutions (DFIs), high cost of capital, the fragmented financing ecosystem, and the perceived risks of financing cleantech.

On the issue of limited access to long-term capital for cleantech manufacturers, participants noted that high capital requirements and long gestation periods hinder their ability to secure financing. Participants highlighted that DFIs, currently provide limited support for large-scale cleantech projects due to risk aversion and the absence of targeted mandates. The high cost of capital, driven by elevated interest rates and a lack of concessional financing, further hampers the financial viability of these projects.

Additionally, the fragmented ecosystem, characterized by poor coordination among stakeholders like private investors, government bodies, and DFIs, creates inefficiencies in mobilizing funds. The perceived risks in cleantech, including market uncertainty, regulatory hurdles, and potential technology obsolescence, were also noted as significant barriers for investors. Another critical concern was the large funding gap in India's climate transition, where only USD 44 Bn of the required USD 120-140 Bn is mobilized annually, with a low leverage ratio of 1:1.2 between public and private funding.

Participants provided several suggestions to address these challenges. At the macro level, ensuring policy certainty was identified as essential for setting long-term market expectations. While capital is available in the market, its flow into India is hindered by the perceived lack of viable business models and the limited integration of the Indian ecosystem into the global supply chain. To address the issue of business models, interventions in the financial sector were explored, such as categorizing climate lending as a priority sector, assigning lower risk weightages to climate-related lending portfolios, and promoting awareness for climate investments to redirect household savings and mobilize green bonds. The creation of 'Green Finance NBFCs' with clear mandates to mitigate investor concerns about policy stability was also suggested.

Participants emphasized the need to improve capital efficiency to ease access to finance for cleantech manufacturers. They noted the critical relationship between finance and technology, particularly in securing access to critical minerals essential for green tech manufacturing. Developing refining and processing capabilities, though capital-intensive, was seen as vital. They noted that while capital may be available, it was more important to enabling access to technology as well. Global partnerships for technology transfer, especially between governments and state-owned enterprises, was highlighted as a way to enhance access to these mature technologies, along with mechanisms such as demand aggregation to enhance the purchasing power of the Global South.

Non-conventional financial instruments, like mezzanine funding, were recommended to increase capital flow to cleantech manufacturing. Participants also underscored the importance of involving DFIs for focused capital allocation and suggested government interventions to derisk investments through instruments like partial guarantees and inclusion in priority sector lending. They also proposed leveraging Corporate Social Responsibility (CSR) funding by setting sectoral targets.

Building domestic technology capabilities through increased translational research in Indian universities and research institutions was identified as an urgent need. Participants noted a need to bridge the gap observed in Technology Readiness Level 3 to Level 7 for advanced technologies, with access to technology being viewed as a key risk by many global VCs and investors. Establishing widely accepted technology standards to facilitate finance flow was also recommended. Additionally, participants stressed the role of legacy firms in mentoring startups to streamline value chains and enhance operational fundamentals.

To increase domestic investments, innovative financial instruments like green bonds and green indices were suggested, particularly in light of the low participation of Indian households in stock markets. These measures aim to enhance the share of capital available for green tech manufacturing and support India's climate transition goals.

201.Bloomberg NEF, Energy Transition Investment trend, 2024
202.Dalberg's analysis

Bharat Climate Forum 2025

INVEST INDIA THE WORLD BANK

BHARAT CLEANTECH MANUFACTURING PLATFORM

CONCLUSION OF BHARAT CLIMATE FORUM AND PLAN AHEAD

Building on the success of the **Bharat Climate Forum 2025,** the aim to build a cleantech acceleration strategy and action plan are envisioned under the newly launched **Bharat Cleantech Manufacturing Platform (BCMP),** which will be hosted by **Dalberg Advisors and Council for International Economic Understanding (CIEU).**

This platform is intended to catalyze investments, strengthen domestic supply chains, and advance manufacturing capabilities across key sectors to align with India's ambitious decarbonization goals. It will serve as a hub multi-stakeholder collaboration to drive the right interventions and actions to accelerate cleantech capital investments, R&D and innovation, capacity building and partnerships—both national and international. The platform will strive to build a resilient and diversified cleantech manufacturing supply chain network that reinforces India's leadership in the global transition to low-carbon, climate-resilient economies.

Goals of Bharat Cleantech Manufacturing Platform

The Bharat Cleantech Manufacturing Platform will aim to achieve higher indigenization of cleantech manufacturing supply chains across 6 focus sectors.

- Increasing indigenization levels to **at least 50%** for **Solar energy, E-mobility, BESS and Green Hydrogen** value chains
- Increasing indigenization levels by 10-20% for **Wind energy and bio-energy value chains to 80-90%** levels

These goals are summarized in Figure 24.

Figure 24: Goals of the Bharat Cleantech Manufacturing Platform

Sector-wise goals

	Solar	Wind	BESS	E-mobility	Green Hydrogen	Bioenergy
Installed capacity						
2030 NDC targets	300 GW	100 GW	230-240 GWh[1]	30@30	5 MTPA	15 GW
% value chain indigenization						
Current levels	20%	58-70%	11-25%	30-40%[2]	Nascent	70-80%
2030 target	50%	80-90%	40-55%	50-60%	50%	80-90%

May decline due to shifting and unstable demand of domestic components amid intensified global competition

Only for bioenergy production, downstream indigenization challenges persist

(1) Estimated requirements under National Electricity Plan (NEP) 2023 of CEA; (2) For EV Motors and controllers

Source: MNRE, Ministry of Power; Economics Times; BNEF's installed and announced capacity; IEA, India – World Energy Investment 2024 – Analysis; NITI, India's Power Sector | Capacity & Generation Mix; PIB, India's Ethanol Push: A Path to Energy Security, National Electricity Plan (NEP) 2023 of Central Electricity Authority (CEA); EV Reporter, India's electric vehicle supply chain landscape | An overview, 2024

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Key objectives of the Platform

The key objectives of the platform include

- Building collaborative milestone-based action plans
- Facilitating knowledge sharing and best practices
- Strengthening collaboration and investment
- Increasing affordability & access for developing economies

Over the coming months, the Platform will focus on developing a detailed strategy and action plan to accelerate indigenization of manufacturing capacity across the focus sectors of **Solar Energy, Wind Energy, Battery Energy Storage Systems (BESS), E-mobility, Green Hydrogen and Bioenergy**

As a part of this strategy, the platform will focus on identifying interventions under key pillars relevant to each sector which would have the highest impact on driving indigenization.

The key pillars that the strategy will focus on include:

- **R&D and Technology:** Driving technology sharing, adoption and indigenous R&D, including collaborations and partnerships
- **Workforce:** Bridging skilling gaps for specialized and non-specialized workforce roles
- **CAPEX and Infrastructure:** Addressing machinery sourcing & infrastructure requirements (e.g., grid connectivity, transportation hubs)
- **Financing:** Identifying financial instruments and mechanisms to reduce the funding gap and drive investment
- **Upstream:** Streamlining raw material sourcing (e.g. critical rare earth elements; bio-energy feedstock etc.)
- **Downstream:** Driving demand creation, including among intermediate and end customers, and adoption of output

To build this strategy and action plan, the Platform will conduct sector specific assessments along with our knowledge partners to identify gaps and challenges, potential solutions and enablers for each combination of sector and pillar. This will subsequently be followed by pillar-level convenings with multiple stakeholders and experts to build clear sector-pillar level interventions. The enablers to support these interventions would be spread across **policy, trade partnerships, public and private stakeholder recommendations and demand and supply drivers.**

The identification of these sector-pillar interventions and the creation of a comprehensive strategy and action plan will then lead to further **sector specific activities aimed at operationalizing the pillars** and moving towards achieving the value chain indigenization goals which would be addressed over a longer time period by the Platform and relevant stakeholders to help achieve the platform goals.

Council for
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Council for International Economic Understanding (CIEU) is an independent research oriented think-tank based out of New Delhi. We look forward to encouraging in-depth research, exchange dialogues, curate ideas leading to resolving the issues of the last man standing

COUNCIL FOR INTERNATIONAL ECONOMIC UNDERSTANDING
L-1403, Prateek Laurel, Sector 120, Noida

am@ cieu.in | @ cieu _ official | www.cieu.in | Cieu India

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Dalberg Advisors is a strategic advisory firm combining the best of private sector strategy skills and rigorous analytical capabilities with deep knowledge and networks across emerging and frontier markets. We work collaboratively across the public, private and philanthropic sectors to fuel inclusive growth and help clients achieve their goals.

N-102, Second Floor,
B Panchsheel Park, New Delhi,
Delhi 110017, India

Dalberg | @DalbergTweet | www.dalberg.com

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