

Indo-German Collaboration in Green Technology: Pathways to Global Sustainable Development

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ABSTRACT

Environmental sustainability has, over the years, become one of the key pillars on which international partnerships are being built. Countries around the world are leaning into it --- not just as a moral imperative but as a practical pathway to fight climate change, shift toward cleaner energy, and pursue growth that does not come at the planet's expense. Within this broader trend, the Indo-German relationship offers a particularly interesting case. Both nations have made sustainability a centerpiece of their cooperation, yet the question of how deeply this commitment actually runs --- and what it looks like on the ground --- has not been explored as thoroughly as one might expect. Most of the existing literature stays at the level of policy dialogue and diplomatic frameworks. What is less understood is how bilateral partnerships translate into tangible corporate sustainability performance. That gap is what this study sets out to address, by examining the role environmental sustainability plays in strengthening Indo-German ties --- through the specific channels of green technology, renewable energy, climate finance, and sustainable development.

The study follows a descriptive and comparative case study design and relies entirely on secondary data gathered between 2021 and 2025. At the policy level, the analysis is anchored in the Green and Sustainable Development Partnership --- the flagship bilateral agreement between India and Germany. At the corporate level, it examines the comparative sustainability profiles of four selected firms: RWE AG and thyssenkrupp nucera from Germany, and Reliance Industries Limited and Adani Green Energy Limited from India. The comparison draws on a range of indicators spanning financial performance, environmental outcomes, operational metrics, and green technology adoption.

What the findings reveal is that environmental sustainability has moved well beyond rhetoric in the Indo-German context --- it now represents a genuinely substantial area of engagement.

At the same time, the two sides bring different strengths to the table. German firms tend to lead on technological advancement, green hydrogen capabilities, R&D intensity, and the maturity of their sustainability reporting. Indian firms, on the other hand, stand out in the sheer scale of their renewable energy operations and their capacity to pull off large-scale infrastructure projects at speed. The most promising avenues for deeper cooperation between the two countries include green hydrogen, renewable energy deployment, climate finance, technology transfer, and joint research. That said, real challenges remain. Legal and regulatory frameworks are not always in sync. The cost of green technology is still high. Financing mechanisms are not as accessible as they need to be. Workforce readiness varies across sectors, and ESG reporting standards differ in ways that make cross-country comparisons difficult.

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1. Introduction

Environmental sustainability has become one of the most important priorities for governments, businesses, and international organizations as the world continues to face climate change, biodiversity loss, and increasing environmental degradation. Sustainable development requires countries to balance economic growth with environmental protection while ensuring social well-being for present and future generations. As global environmental challenges become more complex, international cooperation has emerged as an essential strategy for promoting clean technologies, reducing greenhouse gas emissions, and achieving the Sustainable Development Goals (SDGs).

India and Germany have developed a strong strategic partnership in the field of environmental sustainability over the past several years. Germany is recognized globally for its leadership in renewable energy, green hydrogen, environmental governance, and advanced sustainable technologies. India, on the other hand, has become one of the fastest-growing economies while making significant investments in renewable energy, solar power, wind energy, electric mobility, and climate-resilient infrastructure. Through initiatives such as the Green and Sustainable Development Partnership (GSDP), both countries have strengthened cooperation in areas including clean energy, green hydrogen production, climate finance, circular economy practices, sustainable urban development, and technological innovation.

The growing collaboration between India and Germany demonstrates how international partnerships can accelerate sustainable economic development while addressing environmental challenges. Germany contributes advanced technological expertise, financial assistance, research capabilities, and policy frameworks, whereas India provides large-scale implementation opportunities, expanding renewable energy markets, and manufacturing capacity. This complementary relationship enables both countries to exchange knowledge, develop innovative environmental solutions, and promote sustainable industrial development.

At the corporate level, sustainability has become a strategic priority for organisations seeking long-term competitiveness and responsible business growth. Companies increasingly invest in renewable energy projects, carbon emission reduction, environmental, social and governance (ESG) initiatives, green hydrogen technologies, and sustainable manufacturing processes. Organisations such as RWE AG, thyssenkrupp nucera, Reliance Industries Limited, and Adani Green Energy Limited represent significant contributors to sustainable development within their respective countries through continuous investment in clean energy technologies and environmental innovation.

Despite considerable progress, several challenges continue to affect Indo-German environmental cooperation. Differences in regulatory frameworks, sustainability reporting standards, climate financing mechanisms, technological costs, and policy implementation create barriers to achieving greater collaboration. Furthermore, rapidly changing environmental regulations and increasing global sustainability expectations require governments and corporations to continuously innovate while maintaining economic competitiveness.

The increasing importance of sustainability has also generated significant academic research focusing on renewable energy development, ESG performance, climate policy, green technology, and international environmental partnerships. However, relatively fewer studies have comprehensively examined Indo-German sustainability cooperation by integrating bilateral policy initiatives with comparative corporate sustainability performance. Therefore, this study aims to provide a holistic understanding of environmental sustainability in Indo-German relations by examining government initiatives, corporate sustainability performance, green technology cooperation, and future opportunities for strengthening bilateral environmental collaboration

2. Literature Review

Various scholars have investigated the strategic alliance between India and Germany, focusing on renewable energy projects, climate finance mechanisms, and international cooperation in green technology. These investigations offer significant perspectives on how geopolitical partnerships, innovative technologies, and bilateral commerce contribute to the advancement of global sustainable development.

Kuszevska-Bohnert (2025) analyzed the transformation of German policy toward India, shifting from an economic emphasis to a comprehensive partnership that highlights security, democratic principles, and the green economy. The research noted that shifting global geopolitics compel both nations to prioritize security and supply chain resilience, with sustainability serving as a foundational element of their cooperation. The study determined that integrating India's developmental potential with Germany's technical proficiency is vital for tackling global issues, despite persistent difficulties in aligning national interests with varied political strategies.

García Bermejo (2023) explored the transition of Indo-German relations from a conventional donor-recipient model to a strategic alliance centered on renewable power and digital networks. The inquiry observed that Germany provides assistance through organizations such as BMZ, KfW, and GIZ, emphasizing environmental and social systems in India, including the KfW-funded Sakri Solar Power Plant. It was concluded that collaborative efforts, aligned with the EU Green Deal, effectively lower emissions while delivering clean energy and fostering sustainable urban growth.

Kuszevska-Bohnert (2025) contended that Germany is transitioning from its traditional role as a civilian power toward pragmatic realism, influenced by a multipolar environment and international conflicts. The analysis mentioned that via the 2024 "Focus on India" framework, Germany identifies India as a crucial democratic partner in the Indo-Pacific, seeking intensified cooperation in defense, commerce, and environmental sectors. The report concluded that Germany emphasizes strategic defense and connectivity to assist India against regional pressures, notwithstanding ideological differences regarding democratic governance.

Chakravorty (2023) mapped regional advancements in India regarding SDG 7 objectives for accessible and clean power. The document noted that while national electrification has improved, significant geographic gaps remain in clean fuel access and regional energy distribution. It determined that resolving these disparities requires addressing underperforming utility providers and expanding local solar initiatives rather than just implementing national policies, pointing to effective state-level models.

Jaspal (2024) detailed India-EU discussions on green recovery, noting that public funding for climate action is insufficient and requires private investment. The study analyzed the disagreement over the EU's Carbon Border Adjustment Mechanism (CBAM), viewed by India as a trade barrier while the EU deems it necessary for preventing carbon leakage. It was concluded that developing compromises, like shared reporting standards within "Climate Clubs," is essential for drawing private capital into low-cost markets for emission reduction without causing unilateral tension.

Agarwal (2024) investigated the evolution of India and Germany from a distant post-Cold War relationship to a robust alliance focused on trade, technology, and global solutions. The research noted that the partnership pairs India's massive market and workforce with Germany's industrial expertise and clean energy solutions. It concluded that future reliability in supply chains and sustainable growth depends on deeper integration to produce scalable environmental manufacturing solutions.

Aithal and Aithal (2016) described the vital role of green technology in mitigating pollution and climate change while driving economic expansion. The paper noted that implementing sustainable practices in renewable energy and waste management generates business prospects, fosters innovation, and enhances organizational sustainability. It concluded that sustained government backing through financial incentives and research funding is necessary to manage high costs and achieve widespread adoption in the current century.

Saravanan (2026) evaluated two decades of trade data, identifying Germany as a primary economic ally for India in the European Union. The study showed steady growth in bilateral trade despite global economic shifts, with India providing engineering and IT services while importing German machinery and environmental technologies. It determined that addressing trade obstacles and regulatory variations is vital for expanding this economic alliance and providing mutual benefits to both nations.

The Observer Research Foundation and Konrad Adenauer Stiftung (2024) explored the increasing cooperation between India and Germany to mitigate climate change and support responsible global development. The report noted that the alliance focuses on digital shifts and green innovation, combining German clean tech with India's growing economy. It concluded that bridging investment deficits and policy gaps is essential for strengthening this partnership and promoting international green multilateralism.

Kumar (2026) examined how India and Germany collaborate on development initiatives in African nations through triangular cooperation. The policy brief noted that this model merges Germany's technical and financial resources with India's cost-effective solutions and experience in the Global South in sectors like healthcare and renewable energy. It concluded that improved coordination, ongoing dialogue, and defined institutional roles are required to manage funding hurdles and foster inclusive sustainability in Africa.

The existing literature demonstrates that environmental sustainability has become a major focus of international cooperation. While numerous studies examine renewable energy, climate policy, ESG reporting, and green technologies individually, limited research integrates bilateral government initiatives with comparative corporate sustainability performance.

2.1 What previous studies covered

The reviewed literature indicates that previous studies have extensively examined renewable energy development, climate policy, ESG reporting, green hydrogen technologies, sustainable infrastructure, and Indo-German environmental cooperation. Similarly, international organizations such as OECD, IEA, UNEP, World Bank, and NITI Aayog have emphasized the importance of sustainability, climate finance, and technological innovation in achieving sustainable development.

3. Research Gap

However, the existing literature primarily investigates these themes separately. Most studies focus either on bilateral policy initiatives or on corporate sustainability practices. Limited research integrates government-level sustainability cooperation with a comparative assessment of Indian and German companies using financial, environmental, and sustainability indicators. Furthermore, very few studies simultaneously evaluate bilateral cooperation, corporate sustainability performance, and future opportunities and challenges within a single analytical framework.

3.1 How our study fills the gap

To address this gap, the present study combines policy-level analysis with a comparative evaluation of selected Indian and German companies. The study examines bilateral sustainability initiatives while assessing corporate sustainability performance through selected financial, environmental, and green technology variables. This integrated approach provides a broader understanding of the contribution of Indo-German collaboration toward sustainable development.

4. Objectives of the Study

The present study has been undertaken to examine the growing importance of environmental sustainability in Indo-German relations by analyzing bilateral cooperation, corporate sustainability performance, and future opportunities in green technology. The specific objectives of the study are:

1. To examine the role of environmental sustainability in strengthening Indo-German bilateral relations through green technology cooperation, renewable energy initiatives, and sustainable development policies.
2. To examine the comparative sustainability profiles of selected Indian and German companies using environmental, operational, financial, and sustainability indicators.
3. To identify the opportunities and challenges associated with Indo-German collaboration in renewable energy, green hydrogen, climate finance, and sustainable industrial development.

5. Research Methodology

5.1 Research Design

The present study adopts a descriptive and comparative research design to examine environmental sustainability in Indo-German relations. The research investigates how bilateral cooperation between India and Germany promotes renewable energy development, green technology innovation, climate action, and sustainable economic growth. A comparative analysis has also been conducted to evaluate the sustainability performance of selected Indian and German companies operating in the renewable energy and green technology sectors.

The study is based entirely on secondary data collected from authentic and reliable sources. The descriptive approach helps explain the existing sustainability initiatives and bilateral partnerships, while the comparative approach enables an evaluation of corporate sustainability performance across both countries. This research design provides a comprehensive understanding of the contribution of governments and businesses toward achieving environmental sustainability.

5.2 Scope of the Study

The study focuses on the environmental sustainability partnership between India and Germany. It examines bilateral initiatives such as GSDP, climate finance, renewable energy collaboration, and technology transfer, along with the sustainability performance of selected Indian and German companies. The analysis is based on secondary data covering the period from 2021 to 2025.

5.3 Research Questions

In accordance with the aforementioned objectives, this investigation is directed by the following research inquiries designed to explore the dimensions of Indo-German environmental partnership:

RQ1: In what ways has the focus on environmental sustainability enhanced the strategic alliance between India and Germany through advancements in green technology and renewable power ventures?

RQ2: To what extent do representative corporations from India and Germany differ when evaluated against financial, operational, and ecological sustainability metrics?

RQ3: Which primary drivers and systemic barriers impact the progression of bilateral efforts in areas such as climate finance, green hydrogen development, and renewable energy infrastructure?

5.4 Sample Selected

The study focuses on four leading companies that actively contribute to renewable energy development, green technology, and sustainable business practices in India and Germany.

5.5 Selected Companies

- RWE AG (Germany) → large-scale renewable-energy generation
- Thyssenkrupp nucera (Germany) → electrolyzer/green-hydrogen technology
- Reliance Industries Limited (India) → large-scale Indian investment in renewable and emerging clean-energy technologies
- Adani Green Energy Limited (India) → large-scale renewable-energy deployment in India

5.5.1 RWE AG

RWE AG is a leading German energy company headquartered in Essen, Germany. Founded in 1898, the company has transformed itself into one of Europe's largest producers of renewable energy through significant investments in offshore wind, onshore wind, solar power, battery storage, and green hydrogen projects. RWE plays a major role in Germany's energy transition and has established ambitious carbon reduction targets aligned with international climate goals. The company was selected for this study because of its leadership in renewable energy generation,

strong ESG initiatives, and comprehensive sustainability reporting, making it an appropriate representative of Germany's green energy sector.

5.5.2 Thyssenkrupp nucera

thyssenkrupp nucera AG & Co. KGaA is a German green technology company headquartered in Dortmund, Germany. It specializes in industrial-scale water electrolysis systems for green hydrogen production and is recognized as a global leader in hydrogen technologies. The company invests heavily in research and innovation to support industrial decarbonization and the transition to clean energy. It was selected for this study because of its technological leadership in green hydrogen and its relevance to Indo-German cooperation in sustainable industrial development.

5.5.3 Reliance Industries Limited

Reliance Industries Limited (RIL) is an Indian multinational conglomerate headquartered in Mumbai, India. Founded in 1973, the company has expanded beyond petrochemicals and refining into renewable energy, solar manufacturing, green hydrogen, battery storage, and clean energy infrastructure. Through its New Energy business, Reliance aims to support India's transition toward a low-carbon economy. The company was selected due to its substantial investments in green technologies, large-scale sustainability initiatives, and strategic role in India's renewable energy sector.

5.5.4 Adani Green Energy Limited

Adani Green Energy Limited (AGEL) is one of India's largest renewable energy companies, headquartered in Ahmedabad, Gujarat. Established in 2015, the company develops, owns, and operates utility-scale solar, wind, and hybrid renewable energy projects across India. AGEL has rapidly expanded its renewable energy capacity and plays a significant role in helping India achieve its clean energy targets. The company was selected because of its leadership in renewable energy deployment, extensive sustainability initiatives, and strong contribution to India's green energy transition.

The selected companies were chosen using purposive sampling because they represent leading organizations in renewable energy and green technology in their respective countries. They have significant investments in sustainability, regularly publish annual and sustainability reports, and actively participate in renewable energy and green hydrogen initiatives. Their publicly available disclosures make them suitable for comparative analysis.

These companies have been selected because of their significant investments in renewable energy, green hydrogen technologies, environmental sustainability, and innovation. They also provide sufficient publicly available information through annual reports, sustainability reports, and investor publications, making them suitable for comparative analysis.

The study further examines the environmental cooperation between India and Germany, particularly under initiatives such as the Green and Sustainable Development Partnership (GSDP), renewable energy collaborations, and climate-focused policy frameworks.

5.6 Sources of Data

The present study is based exclusively on secondary data collected from various reliable and authentic sources. Information has been gathered from:

- Annual Reports
- Sustainability Reports
- ESG Reports
- Official Company Websites
- Government Publications
- Ministry of External Affairs Reports

- Green and Sustainable Development Partnership (GSDP) documents
- International Energy Agency (IEA) Reports
- OECD Publications
- United Nations Environment Programme (UNEP) Reports
- World Bank Reports
- Research Journals
- Industry Reports
- Business Publications

The collected information includes financial performance, renewable energy capacity, carbon emissions, ESG performance, green investments, sustainability initiatives, environmental policies, and bilateral cooperation projects between India and Germany.

5.7 Justification for Company Selection

The four companies were purposively selected because they represent important dimensions of the India–Germany green-transition relationship. RWE AG represents large-scale renewable-energy generation in Germany; thyssenkrupp nucera represents green-hydrogen and electrolyzer technology; Reliance Industries Limited represents large-scale Indian investment in renewable and emerging clean-energy technologies; and Adani Green Energy Limited represents large-scale renewable-energy deployment in India. The companies were also selected because substantial information is publicly available through annual reports, sustainability reports, ESG disclosures, and investor publications covering the 2021–2025 study period.

5.8 Indicators Selected and Measurement Framework

For the purpose of analysis, **twelve variables** have been selected to evaluate corporate sustainability performance and Indo-German collaboration in green technology and sustainable development. The selected variables are:

Dimension	Indicator	Measurement
Bilateral cooperation	GSDP	Qualitative assessment
Technology	Technology transfer	Qualitative evidence
Renewable energy	Renewable/clean-energy capacity	GW, where applicable
Financial	Revenue	USD billion
Financial	Net profit	USD billion
Environmental	Scope 1+2 emissions	MtCO ₂ e
Sustainability	ESG score	Published ESG rating/score
Investment	Green investment	USD billion, where available
Hydrogen	Hydrogen projects	Number/status
Innovation	R&D	Reported expenditure/evidence
Climate finance	Climate finance	Qualitative/financial evidence
Cooperation	Renewable-energy collaboration	Qualitative evidence

The four companies were purposively selected because they represent important dimensions of the India–Germany green-transition relationship. RWE represents large-scale renewable-energy generation, thyssenkrupp nucera represents green-hydrogen and electrolyzer technology, Reliance Industries represents large-scale Indian investment in renewable and emerging clean-energy technologies, and Adani Green Energy represents large-scale renewable-energy deployment in India.

Because the selected companies operate under different business models and industry segments, they are not directly comparable across all indicators. The corporate comparison is therefore indicator-specific rather than a direct ranking

of overall sustainability performance. Commonly reported indicators such as financial performance, environmental performance, emissions, ESG ratings, and green investment are examined where comparable data are available. Company-specific indicators, such as electrolyzer capacity for thyssenkrupp nucera, are interpreted within the relevant business context.

For the selected companies, renewable-energy capacity is used as the operational indicator for RWE, Reliance Industries, and Adani Green Energy, whereas electrolyzer capacity is used for thyssenkrupp nucera because of its business focus on electrolyzer and green-hydrogen technology. Therefore, these capacity indicators are interpreted within the respective business contexts and are not treated as directly comparable measures of overall sustainability performance.

The availability and measurement of indicators vary across companies because of differences in business models, reporting frameworks, and disclosure practices. Where standardized quantitative data are unavailable, qualitative evidence is used.

Because the selected companies operate under different business models and industry segments, the corporate comparison is indicator-specific rather than a direct ranking of overall sustainability performance. Renewable-energy capacity is used for RWE AG, Reliance Industries Limited, and Adani Green Energy Limited because renewable-energy generation and deployment are relevant to their respective businesses. For thyssenkrupp nucera, electrolyzer-related capacity is used as a company-specific operational indicator because its principal business relates to electrolyzer and green-hydrogen technology. The electrolyzer capacity figures are therefore not treated as directly equivalent to renewable-generation capacity figures.

These variables were selected because they directly align with the objectives of the study. The first four variables assess bilateral cooperation between India and Germany, the next six evaluate the sustainability and financial performance of the selected companies, and the final two examine innovation and green technology initiatives. This methodology provides a structured framework for evaluating both corporate sustainability performance and the broader environmental partnership between India and Germany. The selected variables enable a comprehensive comparison of organizational sustainability practices while also assessing the effectiveness of bilateral cooperation in promoting green technology, renewable energy, and long-term sustainable development.

Because the selected companies follow different reporting calendars and fiscal-year conventions, reported figures are retained according to each company's official reporting period. Year labels should therefore be interpreted as the respective reporting year rather than assumed to represent identical calendar-year periods.

5.9 Method of Comparative Analysis

The comparative evaluation was conducted using descriptive analysis of selected indicators covering the 2021–2025 study period. Year-wise company data were compiled from annual reports, sustainability reports, ESG disclosures, and other official company publications. Growth trends were calculated where consistent data were available. Cross-company comparison was conducted on indicators that were sufficiently comparable, including financial performance, emissions, ESG reporting, and selected sustainability measures. Where companies operate under different business models, company-specific indicators were interpreted within their respective business contexts. For example, renewable-energy capacity was used for RWE AG, Reliance Industries Limited, and Adani Green Energy Limited, while electrolyzer-related capacity was used as a business-specific indicator for thyssenkrupp nucera. The analysis therefore does not constitute a direct ranking of overall sustainability performance. No inferential statistical hypothesis testing was performed because the study uses a descriptive design and a small purposive sample of four companies.

6. The Role of Environmental Sustainability in Strengthening Indo-German Bilateral Relations

Environmental sustainability has become one of the most significant pillars of the strategic partnership between India and Germany. Over the past decade, both countries have expanded their cooperation beyond traditional economic

and diplomatic relations by focusing on climate action, renewable energy, sustainable industrial development, and green technology innovation. The increasing global concern regarding climate change, energy security, and carbon emissions has encouraged both nations to work together in achieving sustainable development while promoting long-term economic growth.

Germany has established itself as a global leader in renewable energy, environmental governance, clean technology, and industrial innovation.

Through continuous investment in research and development, Germany has developed advanced technologies in wind energy, green hydrogen, energy-efficient manufacturing, and carbon reduction strategies. India, on the other hand, has emerged as one of the world's fastest-growing renewable energy markets, making significant progress in solar energy, wind power, electric mobility, and sustainable infrastructure. The complementary strengths of both countries have created opportunities for stronger bilateral cooperation.

The Green and Sustainable Development Partnership (GSDP), launched jointly by India and Germany, has significantly strengthened environmental collaboration between the two countries. Under this partnership, both governments cooperate in areas such as renewable energy expansion, green hydrogen production, climate finance, sustainable urban development, circular economy practices, biodiversity conservation, and clean transportation. These initiatives encourage technology transfer, policy collaboration, investment promotion, and knowledge sharing between government agencies, research institutions, and private organizations.

Figure 1.1: Indo-German Bilateral Trade in Environmental & Green Technology Sectors (2021-2025)

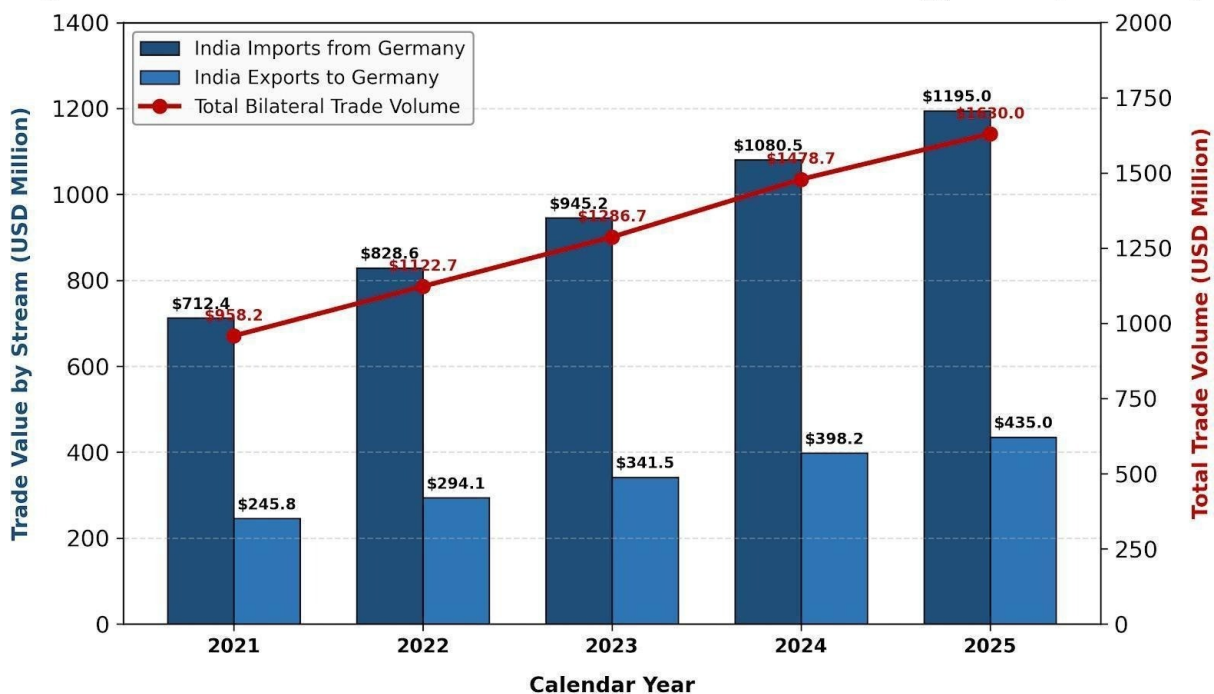


Figure 1: Indo-German Bilateral Trade in Environmental & Green Technology Sectors (2021-2025)

Source: Author's compilation based on Indo-German bilateral trade data, Ministry of External Affairs and GSDP reports (2021-2025).

The study also indicates that environmental sustainability has become an important component of bilateral trade and investment. German companies continue to invest in India's renewable energy sector by introducing advanced technologies, while Indian organizations benefit from German engineering expertise and sustainability practices. Similarly, Indian companies contribute by implementing renewable energy projects on a large scale and supporting global clean energy transitions. Such cooperation has enhanced economic relations while contributing to global climate objectives.

Apart from government initiatives, corporate participation has become equally important in promoting sustainability. Organizations such as RWE AG, thyssenkrupp nucera, Reliance Industries Limited, and Adani Green Energy Limited are investing heavily in renewable energy, green hydrogen, environmental management, and sustainable manufacturing. Their investments demonstrate how public-private collaboration supports bilateral sustainability objectives and strengthens the Indo-German partnership.

The analysis further reveals that international agreements such as the Paris Agreement, the United Nations Sustainable Development Goals (SDGs), and various climate finance initiatives have accelerated Indo-German cooperation. These global commitments have encouraged both countries to adopt cleaner technologies, reduce greenhouse gas emissions, increase renewable energy capacity, and improve environmental governance through collaborative policymaking.

Although substantial progress has been achieved, several challenges continue to influence the effectiveness of Indo-German sustainability cooperation. Differences in environmental regulations, sustainability reporting frameworks, financing mechanisms, technological costs, and implementation strategies sometimes delay collaborative projects. Additionally, varying economic priorities and administrative procedures create challenges in executing large-scale sustainability initiatives. Nevertheless, continuous dialogue, policy coordination, and joint investment programs continue to strengthen bilateral relations.

Overall, the findings suggest that environmental sustainability has evolved from being a policy objective into a strategic partnership that supports economic growth, technological innovation, climate resilience, and sustainable industrial development. The cooperation between India and Germany serves as an excellent example of how international partnerships can contribute to solving global environmental challenges while generating mutual economic benefits.

Interpretation

The findings indicate that environmental sustainability has become a central component of Indo-German bilateral relations. Cooperation through the Green and Sustainable Development Partnership (GSDP), renewable energy initiatives, green hydrogen, climate finance, technology transfer, and environmental policy has strengthened the strategic relationship between the two countries. Germany contributes technological expertise, research capabilities, financial support, and established sustainability practices, while India provides large-scale implementation opportunities and a rapidly expanding renewable energy market. Although regulatory differences, financing constraints, and variations in sustainability reporting remain challenges, continued cooperation among governments, businesses, and research institutions can further strengthen the partnership. Overall, environmental sustainability has emerged as an important foundation of Indo-German cooperation.

7. The Sustainability Performance of Selected Indian and German Companies

The comparative analysis of selected Indian and German companies provides valuable insights into how organizations from both countries contribute to environmental sustainability while maintaining business growth and operational efficiency. The study examines RWE AG, thyssenkrupp nucera, Reliance Industries Limited, and Adani Green Energy Limited, as these companies represent different sectors of the renewable energy and green technology industry while demonstrating strong commitments toward sustainable development.

Corporate sustainability has become an essential component of long-term business strategy. Organizations are increasingly investing in renewable energy, green hydrogen technologies, carbon emission reduction, resource optimization, and Environmental, Social, and Governance (ESG) practices to improve operational efficiency and strengthen their competitive position. The selected companies demonstrate different approaches toward achieving sustainability depending on their business models, technological capabilities, and market environments.

German companies, particularly RWE AG and thyssenkrupp nucera, have established themselves as global leaders in renewable energy generation, green hydrogen production, and sustainable industrial technologies. RWE AG has

significantly expanded its renewable energy portfolio through investments in offshore wind farms, solar energy projects, battery storage systems, and low-carbon electricity generation. The company has also implemented comprehensive carbon reduction strategies while continuously improving environmental reporting and ESG performance.

1. FINANCIAL PERFORMANCE (USD Billion)

Year	Reliance Industries Limited		Adani Green Energy Limited	
	Revenue (USD Billion)	Net Profit (USD Billion)	Revenue (USD Billion)	Net Profit (USD Billion)
2025	126.45	7.73	3.73	0.99
2024	115.22	7.94	3.27	0.84
2023	112.21	7.39	2.73	0.72
2022	105.29	7.58	2.11	0.50
2021	75.59	5.64	1.47	0.32

2. RENEWABLE ENERGY PERFORMANCE

Year	Reliance Industries Limited		Adani Green Energy Limited	
	Renewable Energy Capacity (GW)	Green Investment (USD Billion)	Renewable Energy Capacity (GW)	Green Investment (USD Billion)
2025	10.10	10.00	14.20	2.80
2024	8.40	8.20	11.61	2.30
2023	6.30	6.00	8.26	1.70
2022	4.20	3.00	5.48	1.30
2021	2.70	1.50	2.01	0.70

3. ENVIRONMENTAL PERFORMANCE

Year	Reliance Industries Limited		Adani Green Energy Limited	
	Scope 1+2 Emissions (MtCO ₂ e)	Renewable Electricity Consumption (%)	Scope 1+2 Emissions (MtCO ₂ e)	Renewable Electricity Consumption (%)
2025	67.59	29	0.09	100
2024	70.24	26	0.07	100
2023	68.65	23	0.06	100
2022	69.64	21	0.04	100
2021	67.89	20	0.03	100

4. SUSTAINABILITY & INNOVATION

Year	Reliance Industries Limited		Adani Green Energy Limited	
	ESG Score (MSCI)	Green Hydrogen Projects (Status)	ESG Score (MSCI)	Green Hydrogen Projects (Status)
2025	AA	3 (Operational)	A	1 (Pilot)
2024	AA	3 (Operational)	BBB	1 (Pilot)
2023	AA	2 (Pilot/Operational)	BBB	–
2022	A	1 (Pilot)	BBB	–
2021	A	1 (Pilot)	BBB	–

Note:

- Financial data converted to USD using average yearly exchange rates disclosed in respective annual reports.
- ESG Scores are from MSCI ESG Ratings (latest available as of May 2025).

Sources:

- Reliance Industries Limited – Annual Reports 2021–2025, Sustainability Reports 2021–2025, Investor Relations (www.ril.com)
- Adani Green Energy Limited – Annual Reports 2021–2025, Sustainability Reports 2021–2025, Investor Relations (www.adanigreen.com)
- MSCI ESG Ratings – May 2025 (<https://www.msci.com/our-solutions/esg-investing>)

1. FINANCIAL PERFORMANCE (USD Billion)

Year	RWE AG		thyssenkrupp nucera	
	Revenue (USD Billion)	Net Profit (USD Billion)	Revenue (USD Billion)	Net Profit (USD Billion)
2025	35.35	2.30	1.12	-0.06
2024	30.08	1.67	1.07	-0.05
2023	23.90	0.74	1.01	-0.09
2022	20.28	0.58	0.80	-0.09
2021	18.50	1.10	0.61	-0.08

2. RENEWABLE ENERGY PERFORMANCE

Year	RWE AG		thyssenkrupp nucera	
	Renewable Energy Capacity (GW)	Green Investment (USD Billion)	Renewable Energy Capacity (GW) (Hydrogen Electrolyzer Manufacturing)	Green Investment (USD Billion)
2025	21.30	5.90	2.0	0.45
2024	18.00	5.29	1.5	0.38
2023	16.30	4.60	1.0	0.31
2022	15.20	4.06	0.5	0.27
2021	13.30	3.20	0.3	0.20

3. ENVIRONMENTAL PERFORMANCE

Year	RWE AG		thyssenkrupp nucera	
	Scope 1+2 Emissions (MtCO ₂ e)	Renewable Electricity Generation (%)	Scope 1+2 Emissions (MtCO ₂ e)	Renewable Electricity (Factory Operations) (%)
2025	36.8	83	0.12	100
2024	41.7	80	0.11	100
2023	45.2	74	0.10	100
2022	52.0	71	0.09	100
2021	57.3	65	0.07	100

4. SUSTAINABILITY & INNOVATION

Year	RWE AG		thyssenkrupp nucera	
	ESG Score (MSCI)	Green Hydrogen Projects (Status)	ESG Score (MSCI)	Green Hydrogen Projects (Status)
2025	A	6 (Operational)	BBB	3 (Operational)
2024	A	5 (Operational)	BBB	2 (Operational)
2023	A	4 (Under Development)	BB	1 (Pilot)
2022	A-	3 (Under Development)	BB	1 (Pilot)
2021	A-	2 (Pilot/Development)	BB	1 (Pilot)

Notes:

- Financial data converted to USD using average annual exchange rates disclosed in respective annual reports.
- Scope 1+2 emissions include market-based emissions.

Sources:

- RWE AG – Annual Report 2021, 2022, 2023, 2024, 2025 (rwe.com)
- RWE AG – Sustainability Report 2021, 2022, 2023, 2024, 2025 (rwe.com)
- thyssenkrupp nucera – Annual Report 2021, 2022, 2023, 2024, 2025 (thyssenkrupp-nucera.com)
- thyssenkrupp nucera – Sustainability Report 2021, 2022, 2023, 2024, 2025 (thyssenkrupp-nucera.com)
- MSCI ESG Ratings – May 2025 (msci.com)

Source: Authors' compilation and calculation based on RWE Annual Reports (2021–2025), thyssenkrupp nucera Annual/Sustainability Reports (2021–2025), Reliance Industries Annual Reports (2021–2025), and Adani Green Energy Annual/Sustainability Reports (2021–2025).

Table 2.2: Key Year-on-Year Growth Comparison (2021 vs 2025)

Company	Metric	2021	2025	Change (2021-2025)
RWE AG	Renewable Energy Capacity (GW)	13.30	21.30	+60%
thyssenkrupp nucera	Electrolyzer Capacity (GW)	0.3	2.0	~6.7x
Reliance Industries	Renewable Energy Capacity (GW)	2.70	10.10	+274%
Adani Green Energy	Renewable Energy Capacity (GW)	2.01	14.20	~7x
RWE AG	Net Profit (USD Billion)	1.10	2.30	+109%
thyssenkrupp nucera	Net Profit (USD Billion)	-0.08	-0.06	Still loss-making
Reliance Industries	Net Profit (USD Billion)	5.64	7.73	+37%
Adani Green Energy	Net Profit (USD Billion)	0.32	0.99	+209%
RWE AG	Scope 1+2 Emissions (MtCO ₂ e)	57.3	36.8	-36%
Reliance Industries	Scope 1+2 Emissions (MtCO ₂ e)	67.89	67.59	~flat
RWE AG	ESG Score (MSCI)	A-	A	Improved
Adani Green Energy	ESG Score (MSCI)	BBB	A	Improved

Source: Author's calculation based on Table 2.1 figures (company annual and sustainability reports, 2021-2025).

Similarly, thyssenkrupp nucera has emerged as one of the leading providers of green hydrogen technologies by developing advanced electrolysis systems that support hydrogen production using renewable electricity. Continuous investment in research and technological innovation has enabled the company to strengthen its position within the global clean energy sector while supporting industrial decarbonization.

Indian companies have also demonstrated remarkable progress in environmental sustainability. Reliance Industries Limited has diversified its business by making substantial investments in renewable energy, green hydrogen, solar manufacturing, battery storage, and clean energy infrastructure. Through its long-term sustainability strategy, the company aims to reduce carbon emissions while becoming one of the world's largest producers of green energy technologies.

Adani Green Energy Limited has become one of India's largest renewable energy companies through rapid expansion of solar and wind energy projects. The company continues to increase renewable energy capacity while contributing significantly to India's clean energy transition. Large-scale renewable energy deployment, investment in sustainable infrastructure, and continuous technological improvements have enabled the organization to strengthen its environmental performance.

The comparative analysis indicates that although German companies generally perform better in technological innovation, sustainability reporting, research and development, and green hydrogen technologies, Indian companies demonstrate superior performance in renewable energy expansion, infrastructure development, and project implementation at a much larger scale. Germany emphasizes technological excellence and environmental governance, whereas India focuses on rapid deployment of renewable energy projects to meet increasing energy demands.

Figure 2.2: Comparative Operational and Technological Sustainability Indicators of Selected Companies

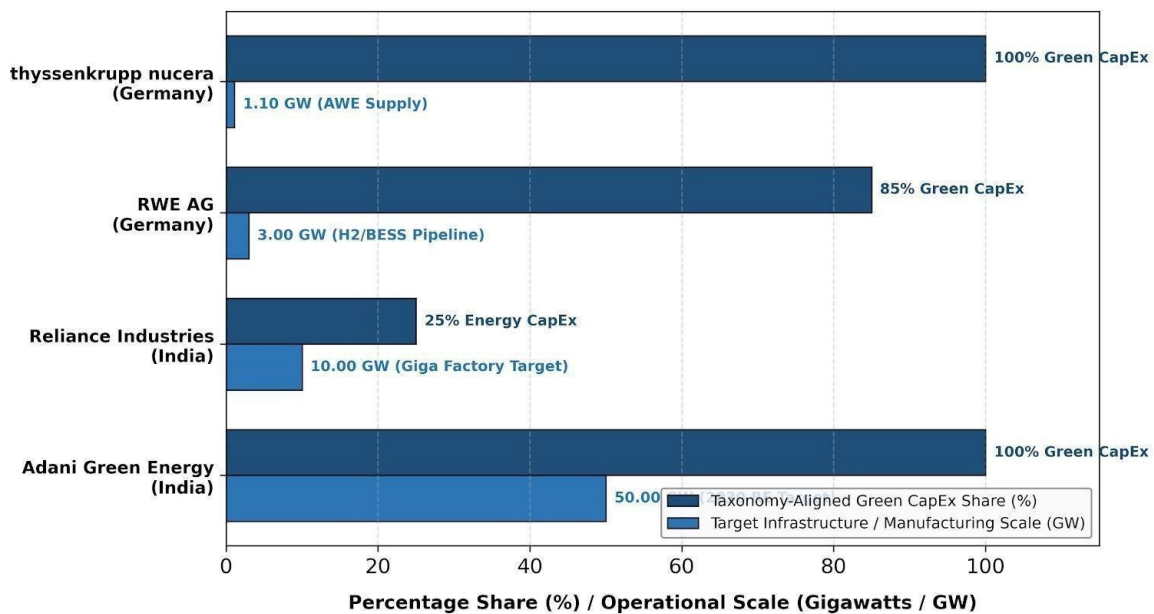
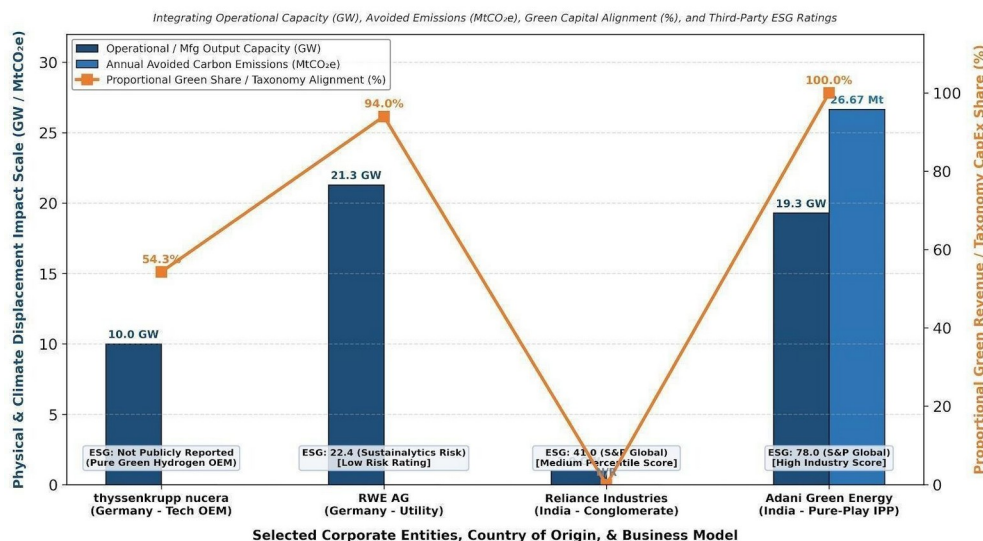


Figure 2: Comparative Operational and Technological Sustainability Indicators of Selected Companies

Environmental indicators such as renewable energy capacity, carbon emission reduction, ESG performance, and green investments show positive progress across all four organizations. Continuous investment in sustainable technologies has improved operational efficiency while reducing environmental impacts. Financial indicators further indicate that sustainability investments increasingly contribute to long-term profitability, risk management, investor confidence, and corporate reputation.

Figure 2.1: Comprehensive Multi-Dimensional Corporate Sustainability Dashboard (2025)**Figure 3: Comprehensive Multi-Dimensional Corporate Sustainability Dashboard (2025)**

The analysis also highlights certain differences in sustainability reporting standards and regulatory frameworks. German companies generally follow more standardized ESG disclosure practices supported by European sustainability regulations, while Indian organizations continue strengthening sustainability reporting in accordance with evolving national and international frameworks. Despite these differences, all selected companies have demonstrated significant commitment toward achieving environmental sustainability through innovation, responsible governance, and strategic investment.

Overall, the comparative study reveals that organizations from both countries contribute significantly to global sustainable development by integrating environmental responsibility into their business operations. Their collective efforts support renewable energy expansion, technological innovation, climate action, and sustainable industrial growth while strengthening the broader environmental partnership between India and Germany.

Interpretation

The comparative analysis shows that sustainability has become an important component of the business strategies of all four selected companies. German companies demonstrate stronger capabilities in technological innovation, green hydrogen, research and development, and sustainability reporting. Indian companies demonstrate greater strength in renewable energy expansion, infrastructure development, and large-scale project implementation. The results therefore indicate a complementary pattern in which Germany contributes technological and research capabilities while India provides significant opportunities for large-scale deployment. Despite differences in reporting standards and regulatory frameworks, sustainability investments are increasingly supporting environmental performance, operational efficiency, and long-term business competitiveness..

8. The Opportunities and Challenges Associated with Indo-German Collaboration

The growing partnership between India and Germany provides significant opportunities for cooperation in renewable energy, green technology, and sustainable development. Germany's technological expertise and India's expanding renewable energy market create complementary strengths that can support long-term collaboration.

Summary of Opportunities and Challenges in Indo-German Environmental Cooperation	
Opportunities	Challenges

Green hydrogen development (electrolysis technology, joint production and export capacity)	Differences in regulatory and environmental policy frameworks between the two countries
Renewable energy expansion (solar, wind, offshore wind, smart grids, battery storage)	High capital cost of advanced green technologies, especially for SMEs
Climate finance (public-private partnerships, development agency funding, green bonds)	Technology transfer and intellectual property protection constraints
Research and technological innovation (joint R&D, AI for environmental management, carbon capture)	Workforce development and shortage of skilled human resources
Sustainable industrial development (circular economy, clean manufacturing, decarbonization)	Inconsistent ESG/sustainability reporting standards and data comparability issues

8.1 Opportunities

Green hydrogen represents one of the most promising areas of cooperation. Germany's expertise in hydrogen technologies and electrolysis can complement India's ambitions to expand green hydrogen production. Joint investment, technology transfer, and research collaboration can support industrial decarbonization and energy security.

Renewable energy provides another major opportunity. India's growing solar and wind capacity creates opportunities for German companies to contribute advanced technologies in areas such as offshore wind, smart grids, energy management, and battery storage.

Combining German technological capabilities with India's large-scale implementation capacity can accelerate renewable energy development.

Climate finance is also important for future cooperation. Increased public-private investment, development financing, and green financing mechanisms can support renewable energy, clean manufacturing, electric mobility, and sustainable infrastructure projects in India.

Joint research and technological innovation can further strengthen the partnership. Universities, research institutions, governments, and industries can collaborate in areas including renewable energy, green hydrogen, circular economy, carbon reduction, and sustainable industrial development.

8.2 Challenges

Despite these opportunities, several challenges remain. Differences in regulatory frameworks, industrial standards, and sustainability reporting requirements can complicate the implementation of joint projects. The high cost of advanced green technologies and the substantial capital requirements of renewable energy, hydrogen, and storage projects can also restrict adoption, particularly among smaller businesses.

Technology transfer, intellectual property protection, and shortages of skilled workers may create additional barriers. Differences in ESG reporting standards and environmental data collection can also make direct comparison of corporate sustainability performance difficult. Addressing these challenges will require stronger policy coordination, improved financing mechanisms, workforce development, and greater consistency in sustainability reporting.

Overall, the opportunities for Indo-German environmental cooperation are substantial. Green hydrogen, renewable energy, climate finance, technology transfer, and joint research can strengthen bilateral relations and contribute to sustainable economic development, provided that regulatory, financial, technological, and workforce-related barriers are effectively addressed.

Figure 3.2: Indo-German Collaboration Framework for Sustainable Development

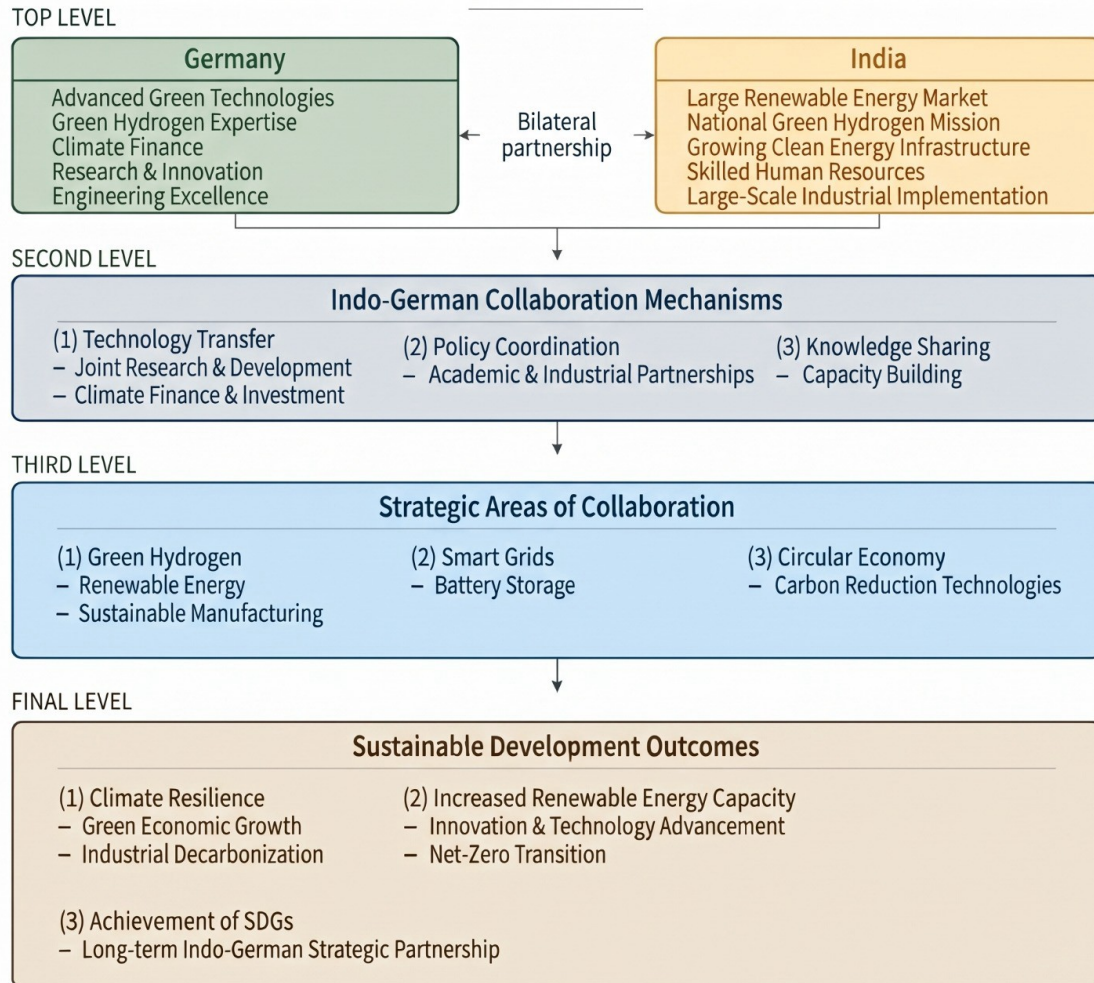


Figure 4: Indo-German Collaboration Framework for Sustainable Development

9. Major Findings

The present study examined the role of environmental sustainability in strengthening Indo-German relations by analyzing bilateral cooperation, corporate sustainability performance, and future opportunities for green technology collaboration. Based on the analysis, the following major findings have been identified:

Table 4.1: Summary of Key Findings by Objective

Objective	Key Finding
Objective 1	Environmental sustainability has become a central and strategic pillar of Indo-German bilateral relations, driven by GSDP, renewable energy cooperation, green hydrogen initiatives, and climate finance.
Objective 2	Both Indian and German companies have integrated sustainability into core business strategy; German firms (RWE AG, thyssenkrupp nucera) lead in technology, R&D and ESG reporting, while Indian firms (Reliance, Adani Green) lead in renewable capacity expansion and large-scale implementation.
Objective 3	The findings indicate that opportunities in green hydrogen, renewable energy, climate finance and R&D appear to outweigh the identified challenges, based on the comparative and qualitative evidence. such as regulatory differences, high technology costs, and inconsistent reporting standards.

1. Environmental sustainability has emerged as a strategic pillar of Indo-German relations. The partnership between India and Germany has expanded beyond traditional diplomatic and economic cooperation to include renewable energy, climate action, green hydrogen, sustainable infrastructure, and environmental governance. These initiatives have strengthened bilateral relations while supporting global sustainable development goals.

2. The Green and Sustainable Development Partnership (GSDP) has significantly enhanced bilateral cooperation. The partnership has encouraged collaboration in renewable energy projects, climate finance, technology transfer, sustainable urban development, and policy coordination. It has also created opportunities for greater public-private participation in environmental initiatives.

3. This complementary Germany-technology / India-scale relationship (detailed under Objective 1) continues to underpin corporate-level cooperation as well, particularly in green hydrogen, renewable energy manufacturing, and environmental governance.

4. Corporate sustainability has become an important driver of business competitiveness and environmental performance. The comparative analysis of RWE AG, thyssenkrupp nucera, Reliance Industries Limited, and Adani Green Energy Limited demonstrates that all selected organizations have integrated sustainability into their business strategies through investments in renewable energy, ESG initiatives, carbon reduction, and technological innovation.

5. German companies demonstrate strong performance in technological innovation and sustainability reporting. Continuous investment in research and development, standardized ESG reporting, green hydrogen technologies, and environmental management systems enables German organizations to maintain global leadership in sustainable industrial development.

6. Indian companies excel in renewable energy expansion and infrastructure development. Large-scale implementation of solar and wind energy projects, increasing investments in green hydrogen, and sustainable infrastructure development have enabled Indian companies to make significant contributions toward India's clean energy transition and global climate goals.

7. Renewable energy and green hydrogen represent the most promising areas for future collaboration. Joint investments, research partnerships, technology transfer, and innovation in these sectors can accelerate clean energy adoption, reduce carbon emissions, and improve energy security for both countries.

8. Climate finance and technological collaboration are essential for achieving long-term sustainability objectives. Financial assistance, investment support, and knowledge sharing between governments, industries, and research institutions can accelerate the implementation of environmentally sustainable projects and strengthen bilateral cooperation.

9. Several challenges continue to influence the effectiveness of Indo-German environmental cooperation. Differences in regulatory frameworks, sustainability reporting standards, technology costs, financing mechanisms, and policy

implementation create obstacles for collaborative projects. Addressing these challenges will require stronger policy coordination, standardized reporting practices, and increased institutional cooperation.

10. Overall, the study confirms that environmental sustainability has become one of the strongest foundations of Indo-German strategic relations. Continued collaboration in renewable energy, green technology, climate finance, research, and sustainable industrial development will not only strengthen bilateral economic relations but also contribute significantly to global climate action and sustainable development.

10. Limitations of the Study

The study is based entirely on secondary data collected from publicly available sources. The analysis is limited to four companies and covers the period from 2021 to 2025. Differences in sustainability reporting frameworks and data availability may affect direct comparability between companies.

11. Future Scope

Future studies may include a larger sample of companies, incorporate primary data through interviews or surveys, and apply advanced statistical techniques such as regression analysis, panel data analysis, or ESG performance indices to provide deeper insights into Indo-German sustainability cooperation.

12. Conclusion

The present study examined the significance of environmental sustainability in strengthening Indo-German relations through bilateral cooperation, corporate sustainability performance, and green technology initiatives. The findings indicate that environmental sustainability has evolved into a key area of collaboration between India and Germany, extending beyond traditional diplomatic and economic relations. Both countries have demonstrated a strong commitment to addressing climate change, promoting renewable energy, and supporting sustainable development through coordinated policies, technological innovation, and strategic partnerships.

The study revealed that initiatives such as the Green and Sustainable Development Partnership (GSDP) have strengthened cooperation in renewable energy, green hydrogen, climate finance, sustainable infrastructure, and environmental governance. Germany contributes advanced technological expertise, research capabilities, and structured sustainability practices, while India provides large-scale implementation opportunities, rapidly expanding renewable energy infrastructure, and a growing clean energy market.

These complementary strengths have enabled both nations to develop mutually beneficial partnerships that contribute to sustainable economic growth and global climate objectives.

The comparative analysis of RWE AG, thyssenkrupp nucera, Reliance Industries Limited, and Adani Green Energy Limited demonstrates that organizations in both countries have successfully integrated sustainability into their long-term business strategies. Investments in renewable energy, green technologies, ESG initiatives, carbon emission reduction, and sustainable manufacturing have improved operational efficiency, strengthened corporate competitiveness, and supported responsible business practices. Among the selected firms, the German companies demonstrate stronger evidence of technological innovation, green-hydrogen capabilities and ESG reporting, while the Indian companies demonstrate stronger renewable-energy capacity expansion and large-scale project implementation.

The study also identified several opportunities for strengthening Indo-German collaboration, particularly in renewable energy, green hydrogen, climate finance, research and development, and technology transfer. At the same time, challenges such as regulatory differences, high technology costs, sustainability reporting variations, and financing constraints continue to influence the effectiveness of bilateral cooperation. Addressing these challenges through stronger policy coordination, standardized reporting frameworks, increased investment, and enhanced research collaboration will further strengthen environmental partnerships between the two countries.

Overall, the study concludes that environmental sustainability has become one of the strongest pillars of Indo-German strategic relations. Continued cooperation between governments, industries, academic institutions, and research organizations will not only enhance bilateral economic and environmental cooperation but also contribute significantly toward achieving global climate goals, sustainable industrial development, and long-term environmental resilience.

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