

## An Empirical Assessment of India's Position in Global Sustainable Bond Market

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### Abstract:

This study aims to examine India's position in the global green bond market and identify areas for improvement to develop its sustainable finance sector. Analysing data from the Luxembourg Green Exchange (1999-2024) and Indian market sources, including Securities and Exchange Board of India, National Stock Exchange, and Climate Bond Initiatives. Findings reveal that green bonds dominate the global market, with the Luxembourg Green Exchange showing the highest variability in bond coupons and maturity durations. In India, the private sector holds a significant 84% market share, with companies issuing various sustainable bonds. However, challenges persist, including lack of standardization, limited investor awareness, and inadequate disclosure and reporting standards. Research findings have implications for policymakers, investors, and issuers, emphasizing the importance of a supportive ecosystem for sustainable finance to flourish in India. Addressing the challenges and leveraging opportunities can help India unlock the full potential of its green bond market and contribute to global sustainable finance efforts. This study contributes to understanding India's green bond market and its potential for growth, highlighting the need for increased standardization, transparency, and alignment with national and international best practices to develop India's sustainable finance sector.

**Keywords:** green finance, sustainable finance, bond, debt, securities.

**JEL Classification:** G12, G14, Q54.

### Introduction

The sustainable finance sector is experiencing rapid growth, reaping attention from academics, policymakers, and industry experts worldwide. Despite voluntary Environmental, Social and Governance (ESG) disclosure initiatives facing challenges, embracing ESG considerations and transparent disclosure can enhance financial performance and reduce information asymmetries. Global public authorities recognize the importance of ESG risks in sustaining economic growth, making ESG integration into investment practices and policy crucial for long-term sustainability (Ghosh et al, 2023). Emerging Market Economies like India have mandated sustainability disclosures for publicly traded entities, aligning with the United Nations Sustainable Development Goals (SDGs), paving the way for streamlined ESG disclosures across sectors.

Sustainable debt financing encompasses alternative investment strategies like green finance, green bonds, and social finance, emerging in response to climate risk and sustainable development concerns. It is essential to distinguish between sustainable debt and bonds, as they serve distinct purposes. Sustainable bonds, including green, social, and sustainability bonds, finance specific initiatives like renewable energy and affordable housing. In contrast, sustainable debt refers to any debt instrument financing projects with positive environmental or social impact.

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Sustainable bonds offer transparency and accountability while ensuring funds are allocated towards sustainable projects. With supportive policies, growing investor demand, and a robust pipeline of sustainable projects, the markets for sustainable debt and bonds are poised for expansion. India's sustainable debt market has shown remarkable growth, highlighting the need for policy development to support market expansion (see Box 1 for details).

The Ministry of Finance has established a Sustainable Finance Task Force, proposing recommendations to drive progress. This supportive policy environment and increasing investor demand are expected to propel market growth. The sustainable debt market plays a crucial role in financing sustainable development initiatives, with green bonds and socially themed bonds gaining popularity, contributing to a more sustainable and equitable future.

Box 1. Highlights of The India Sustainable Debt State of the Market 2021 report

The highlights underscore the significant progress and potential for further expansion of sustainable finance in India, reflecting a growing focus on environmental and social responsibility within the financial sector.

- **Significant Growth:** The Indian sustainable debt market has experienced substantial growth, reaching a total size of USD19.5bn as of 31 December 2021. Indian Green, Social and Sustainability (GSS) debt issuance increased more than six-fold (+585%) to reach USD7.5bn in 2021, following a pandemic-induced decline in issuance in 2020. The cumulative volume has almost doubled in the last two years to represent USD19.5bn in value.
  - Total size of the Indian GSS market: USD18.3bn for green, USD600m for social, and USD500m for sustainability, totalling USD19.5bn.
  - Number of issuers: 72 for green, 1 for social, and 2 for sustainability, totalling 75 issuers.
  - Number of currencies: 3 for green, 1 for social, and 2 for sustainability, totalling 3 currencies.
- **Dominance of Green Bonds:** Green bonds dominate the market, with USD6.4bn in issuance in 2021, followed by social and sustainability bonds.
- **Policy Development:** The report emphasizes the importance of policy development in creating the necessary framework for the growth of the sustainable finance market in India. The Ministry of Finance has established a Sustainable Finance Task Force to develop four pillars of action, including an Indian Taxonomy of sustainable activities, reporting and disclosure, financial policy and regulation, and ecosystem development.
- **Financing Sustainable Development:** Sustainable debt in India serves as a crucial tool for financing projects that contribute to sustainable development and address environmental and social challenges.
- **Expected Continued Growth:** The report anticipates the sustainable debt market in India to continue growing, driven by supportive government policies, and increasing investor demand.

Source: India Sustainable Debt State of the Market 2021 published by Climate Bonds Initiative

Box 1 highlights the significant progress and potential for growth in India's sustainable finance sector, aligning with the global shift towards sustainable development. The utility-scale renewable energy sector has emerged as a key driver of green finance, supported by India's domestic financial systems and project financing ecosystem. The availability of financing has facilitated the issuance of green bonds, reducing the cost of winning bids in renewable energy auctions. Government initiatives, such as Production-Linked Incentive (PLI) programs and incentives for charging infrastructure, have contributed to the growing popularity of electric vehicles (EVs) in India.

The Indian Green, Social, and Sustainability (GSS) bond market exhibits a promising pipeline of projects across diverse industries, indicating significant potential for expansion. The GSS bond market is poised for growth, driven by a robust pipeline of projects. The utility-scale renewable energy sector is expected to remain dominant, supported by resilient asset auction processes and financial community support. The growing popularity of electric vehicles (EVs) presents lucrative growth opportunities, reinforced by government initiatives and incentives. India's commitment to sustainable development is evident in its efforts to foster a regional electric vehicles (EVs) manufacturing ecosystem.

## 1. Literature Review

### 1.1. Global Perspective

Regulatory bodies worldwide are driving climate-related financial transparency, mandating disclosures in the United Kingdom (UK), European Union (EU), Hong Kong, Taiwan, Singapore, and beyond. The UK and EU are leading the charge, with the UK's "comply-or-explain" approach since the financial year 2021–22 and the EU's enhanced Non-Financial Reporting Regulation. By the financial year 2024–2025, all listed issuers must comply with the Task Force on Climate-related Financial Disclosures (TCFD) framework, and other regions are following suit. This global push underscores the critical role of financial markets in addressing climate change, prompting the US Securities and Exchange Commission to intensify its focus on climate-related disclosures (SEBI, 2021).

The Sustainable Debt Global State of the Market report 2022, released by the Climate Bonds Initiative (2023), offers a comprehensive analysis of the rapidly evolving sustainable finance landscape. The report highlights the emergence of Sovereign Sustainability-Linked Bonds (SLBs), a groundbreaking financing instrument that ties repayment costs to national climate and environmental goals. This innovation marks a significant shift towards environmentally conscious investing, with governments and financial institutions exploring new instruments to support climate action and sustainable development. Although investments in social and sustainability bonds declined in 2022 due to reduced COVID-19 activities, the report notes a growing momentum in the sustainable debt market. Countries like Hong Kong, France, and Japan are issuing innovative bonds, demonstrating an increasing commitment to sustainable finance. The World Bank has established key performance indicators for sovereign SLBs, promoting accountability and transparency. The Climate Bonds Initiative (2023) aims to mobilize global funds for climate action and support low-carbon economy projects. Despite a 31% decrease in social and sustainability bonds to \$291.5 billion in 2022, the report emphasizes the importance of sustainable finance in achieving climate goals. Overall, the report highlights the growing significance of sustainable finance in supporting climate action and sustainable development.

The report highlights several noteworthy issues that demonstrate the growing momentum in sustainable finance. China Development Bank and Agricultural Bank of China have been involved in certified green agreements, while Calpine Corporation has secured a USD 1.8 billion approved green loan. Hong Kong SAR has issued a pioneering inflation-linked sovereign green bond, and France and Hong Kong SAR have introduced index-linked bonds to address investor concerns and provide inflation protection. Germany was the largest sovereign green issuer in 2022, and Austria made history by issuing the first green Treasury Bill. Additionally, Uruguay and Chile have issued sustainability-linked bonds tied to key performance indicators related to greenhouse gas emissions and environmental preservation, while Japan has released sustainability bonds with greenium or green-premium pricing. New Zealand has also developed a National Climate Change Risk Assessment and an Emissions Reduction Plan, showcasing the increasing commitment to sustainable finance and climate action globally.

### 2.1. Indian Perspective

The global shift towards sustainable development and addressing climate change has gained significant momentum in recent years. This is reflected in the growing interest among investors in sustainability, as evidenced by the increase in assets and new investments in sustainable funds. The Covid-19 pandemic has further amplified the importance of environmental, social, and governance (ESG) considerations, making them a key priority for investors. As sustainable investing continues to gain popularity, there is a pressing need for enhanced disclosure requirements. In response, global authorities are now mandating more comprehensive ESG disclosures from companies. Additionally, stakeholders and investors are increasingly pushing companies to transparently disclose their ESG practices, risks, and outcomes, driving a surge in demand for greater accountability and transparency.

The impact of climate change on the Indian economy, particularly in relation to how weather patterns affect various economic indicators, is significant. Empirical research conducted by Dilip (2020) underscores the importance of considering climate change risks in macroeconomic analysis and policy formulation. To mitigate these risks, it proposes several policy recommendations, including integrating climate risks into analytical models, addressing data gaps in environmental finance, promoting bank support for environmentally friendly projects, and introducing weather derivatives to mitigate the risk of an unseasonal rainfall.

In an effort to provide valuable information to policymakers, financial institutions, and other stakeholders, Ghosh et. al. (2021) present a comprehensive review of the progress and challenges of green finance in India. Collaboration among policymakers, financial institutions, and other stakeholders is essential to address these issues. The thorough examination of the current state of green financing in India in the article can greatly benefit those seeking to support sustainable economic growth in the country.

Climate-related disasters, referred to as green swan events, pose a significant threat to macroeconomic and financial outcomes due to their potential to cause physical and transitional hazards. This is demonstrated by Ghosh et al (2021). The study highlights the necessity of well-thought-out and globally coordinated strategies to reduce the frequency, severity, and macroeconomic impact of green swan events. Additionally, the study emphasizes the need for adaptation methods to mitigate the impact of natural disasters and the vulnerability of Indian coastal states to them. The findings may assist decision-makers in developing appropriate mitigation and green financing policies.

Ghosh et al (2022) suggests that the shift towards achieving net-zero carbon emissions may pose risks to the Indian banking sector. The income, interest coverage ratio, and non-performing assets of other industries could be affected by the transition to green energy, despite the fact that bank credit is largely derived from just three industries directly linked to fossil fuels. These concerns are being monitored by the Reserve Bank of India, and addressed in its publications. In addition to India's reliance on fossil fuels, the study also discusses international emission guidelines, laws, and policies. Overall, the banking industry is not expected to be particularly vulnerable to disruptions in industries heavily reliant on fossil fuels.

Prakash (2022) emphasizes the importance of Green GDP in measuring the impact of environmental degradation and climate change on national income accounts, particularly in the post-COVID era. The study discusses the concept of the Environmental Kuznets Curve (EKC) in relation to pollution levels and per capita income, and highlights the adverse effects of economic growth on environmental sustainability. It stresses the need for more environmentally friendly and resource-efficient economic growth, while also acknowledging the current discourse surrounding green growth. The process for calculating Green GDP is described, considering the costs of resource depletion, environmental damage, and resource conservation. The report also underscores the significance of regularly monitoring environmental indicators and potential directions for environmental accounting research. Overall, the study indicates that India has made progress towards green growth, but emphasizes the need for additional action and cooperation in areas such as power distribution, electric vehicle charging infrastructure, and financial policy and regulation for adequate funding and green financing.

Jha et al. (2023) utilize a novel modelling technique called multivariate adaptive regression splines (MARS) to examine the impact of climate risk factors on various parameters of agricultural productivity in India. Their findings indicate that precipitation, irrigation water usage, and CO<sub>2</sub> emissions are significant climatic factors affecting agricultural production and productivity in India.

Ghosh et al (2023) analyse input and output inter-linkages between subsectors to estimate the future aggregate and sectoral growth path for the Indian economy. They create a structure to quantify the transition and physical hazards. Reviving the severely damaged economy and transitioning to a greener economy present a challenge for the Indian economy. The green economy's scars from the pandemic were less severe, demonstrating its resilience. The interconnectedness of the brown and green industries should be considered when designing policies. A smooth transition to a greener future requires the right incentives and technological transfer. Sectoral interconnectedness may be a binding obstacle to achieving net-zero policies and sustainable growth.

## **2. Gap in Research**

This paper identifies several research gaps in the literature on sustainable finance in India. Despite progress, the country's green finance industry remains in its infancy, necessitating more coordinated efforts to promote green finance. The Indian green bond market faces numerous challenges, including a lack of standardization, low investor awareness, and inadequate transparency and reporting guidelines. Furthermore, data availability is a significant obstacle to calculating environmental, social, and governance (ESG) indicators and impact assessments. To address these gaps, the paper suggests the need for a reliable ESG database, rating, and communication system, as well as standardized corporate ESG reporting. Additionally, the issuance of a sovereign green bond is expected to stimulate further growth in the domestic green bond market. Ultimately, the development of India's sustainable finance sector requires greater standardization, openness, and alignment with best practices, underscoring the importance of policy formulation in establishing a supportive framework.

India's progress in formulating green finance policies and regulatory frameworks lags behind that of developed countries, despite recent initiatives to stimulate growth in this sector. To effectively inform macro-level policy decisions, a deeper understanding of the micro-level dynamics is necessary. This research seeks to address this need by conducting a detailed examination of the global and Indian sustainable debt markets, exploring emerging trends and dynamics to provide actionable insights for public policy and advocacy efforts. By adopting a granular approach, this research aims to contribute to the development of effective regulatory policies that can support the growth of sustainable finance in India and promote a more environmentally conscious economy.

### 3. Research Objective

This paper aims to evaluate India's position in the green bond market relative to the global market, utilizing listing and trading data from select international markets. The specific objectives of this study are threefold: (a) to conduct a comprehensive review of existing literature and reports to identify challenges and issues unique to the Indian green bond market compared to its global counterparts, (b) to develop a nuanced understanding of the sustainable bond market by categorizing bonds at a disaggregated level based on market type, currency, coupon rate, bond duration, yield, and exchange markets, and (c) to assess India's standing in the sustainable bond market and depict its relative position within the global landscape. By achieving these objectives, this research seeks to provide a detailed analysis of India's green bond market and its position vis-à-vis the global market.

### 4. Research Methodology

#### 4.1. Sources of data

##### (A1) For Global Sustainable Bond

The Luxembourg Green Exchange (LGX) is a groundbreaking platform for trading green assets, launched in 2016 by the Luxembourg Stock Exchange (LuxSE) in collaboration with key partners. As a premier global hub for sustainable finance, the LGX connects issuers of green securities with investors seeking eco-friendly opportunities. With over 3,600 listed securities from 50+ countries, including 1,870 labelled bonds worth €970 billion, the LGX has significantly boosted the green bond market's growth, visibility, and accessibility. By providing a dedicated platform for issuers and investors, the LGX has cemented Luxembourg's status as a leading sustainable finance hub, playing a vital role in the global green finance ecosystem.

##### (A2) For India's Sustainable Bond

###### (i) Nifty India Sovereign Green Bond Jan 2028 Index

The Nifty India Sovereign Green Bond Jan 2028 Index is a specialized benchmark index that tracks the performance of Indian government-issued sovereign green bonds maturing on January 31, 2028. Launched on February 27, 2023, this index provides a targeted measure of India's sovereign green bond market, focusing on bonds that finance environmentally and socially beneficial projects. By monitoring the performance of these bonds, the index offers a valuable tool for investors and market participants to assess the growth and trends in India's green bond market, supporting informed investment decisions and market analysis.

###### (ii) Nifty India Sovereign Green Bond Jan 2033 Index

The Nifty India Sovereign Green Bond Jan 2033 Index is a specialized benchmark that tracks the performance of Indian government-issued, rupee-denominated sovereign green bonds maturing on January 31, 2033. Launched on January 27, 2023, this index provides a targeted and accessible way for investors to participate in India's burgeoning green bond market. To ensure a precise representation of the market, the index includes bonds that meet rigorous eligibility criteria, such as government issuance, rupee denomination, minimum 5-year maturity, and third-party green bond certification. The index is rebalanced semi-annually, with bond weights determining their representation. Calculated and disseminated by the National Stock Exchange of India (NSE), this index offers a reliable and authoritative benchmark for investors seeking to engage with India's sovereign green bond market.

###### (iii) Securities and Exchange Board of India (SEBI)'s Green Debt Securities

In 2017, the Securities and Exchange Board of India (SEBI) took a significant step towards promoting sustainable finance by introducing a circular that standardized the process for issuing green debt securities (GDS). This circular was later integrated into the SEBI regulations and operational guidelines, providing a comprehensive framework for GDS issuance.

SEBI continued to refine the GDS regulatory framework through a consultation paper on green and blue bonds, leading to approved amendments in December, 2022. The updated regulations, effective February 2, 2023, broaden the definition of GDS, modify its scope, and introduce measures to prevent greenwashing. Enhanced disclosure requirements aim to increase transparency and accountability in GDS issuance.

The revised Operational Circular Chapter IX applies to all GDS issued on or after April 1, 2023, with heightened disclosure requirements for new issuances. However, earlier issuances will remain subject to previous disclosure obligations until their proceeds are fully utilized. This regulatory framework specifically governs GDS issuances listed on Indian stock exchanges, with additional requirements applicable to foreign market listings. By

strengthening the GDS regulatory framework, SEBI aims to establish India as a hub for sustainable finance and promote environmentally responsible investing. The updated regulations align with global standards, reflecting SEBI's commitment to fostering a transparent and accountable sustainable finance ecosystem.

#### 4.2. Selection of Variables and Period of Study

Given the available secondary sources of data for both Indian as well as global bond market, following variables are selected to carry out this research:

##### (B1) For Global Bond Market

This study examines the following variables related to bonds listed and traded on the Luxembourg Green Exchange:

- Bond type: Four categories of bonds are considered - Social Bonds, Green Bonds, Sustainability Linked Bonds, and Sustainable Bonds.
- Exchange name: The bonds are listed on the Bourse de Luxembourg, Euro MTF, and Lux SE SOL platforms.
- Bond tenure: The duration of each bond is calculated in months, determined by the difference between the listing date and maturity date.
- Bond coupon rate: The annual return on investment for each bond is recorded.
- Issuing institution: The type of institution issuing each bond is identified (e.g., government, corporate, financial).
- Dominant trading currency: The most frequently traded currency for each bond type is noted.
- Study period: The analysis covers a 25-year period, from 1999 to 2024, providing a comprehensive overview of market trends and developments.

##### (B2) For Indian Bond Market

This study focuses on the following key variables related to green bonds in India:

- Nifty India Sovereign Green Bond Jan 2028 Index: A benchmark index tracking sovereign green bonds maturing in January 2028.
- Nifty India Sovereign Green Bond Jan 2033 Index: A benchmark index tracking sovereign green bonds maturing in January 2033.
- Green Debt Securities: A category of debt instruments specifically issued to finance environmentally friendly projects.
- Green Bond Issuer Type: Classification of issuers by type (e.g., government, corporate, financial institutions).
- Company-Level Bond Issue Information: Detailed data on individual bond issues, including issuer, issue date, maturity date, and other relevant details.

## 5. Research Findings

### (A) Global Sustainable Bond Market

The issuance of sustainable bonds has experienced remarkable growth between 2020 and 2024, with a notable geographic disparity (Table 1). Europe has consistently dominated the market, accounting for the largest share of issuance, peaking at 55.26% in 2021 with a total of 573.176 billion USD. Interestingly, Asia has exhibited a significant upward trajectory, reaching 185.360 billion USD in 2023, representing 24.15% of the total issuance. North America's issuance has remained relatively stable, with a peak of 125.325 billion USD in 2021, accounting for 12.08% of the total. Supranational entities have also played a substantial role, with a peak issuance of 158.710 billion USD in 2020, representing 30.22% of the total. In contrast, Africa, Oceania, and South America have demonstrated relatively modest issuance amounts, yet still exhibit growth. This trend underscores a global shift towards sustainable financing practices, with total issuance increasing from 528.141 billion USD in 2020 to 643.038 billion USD in 2024.

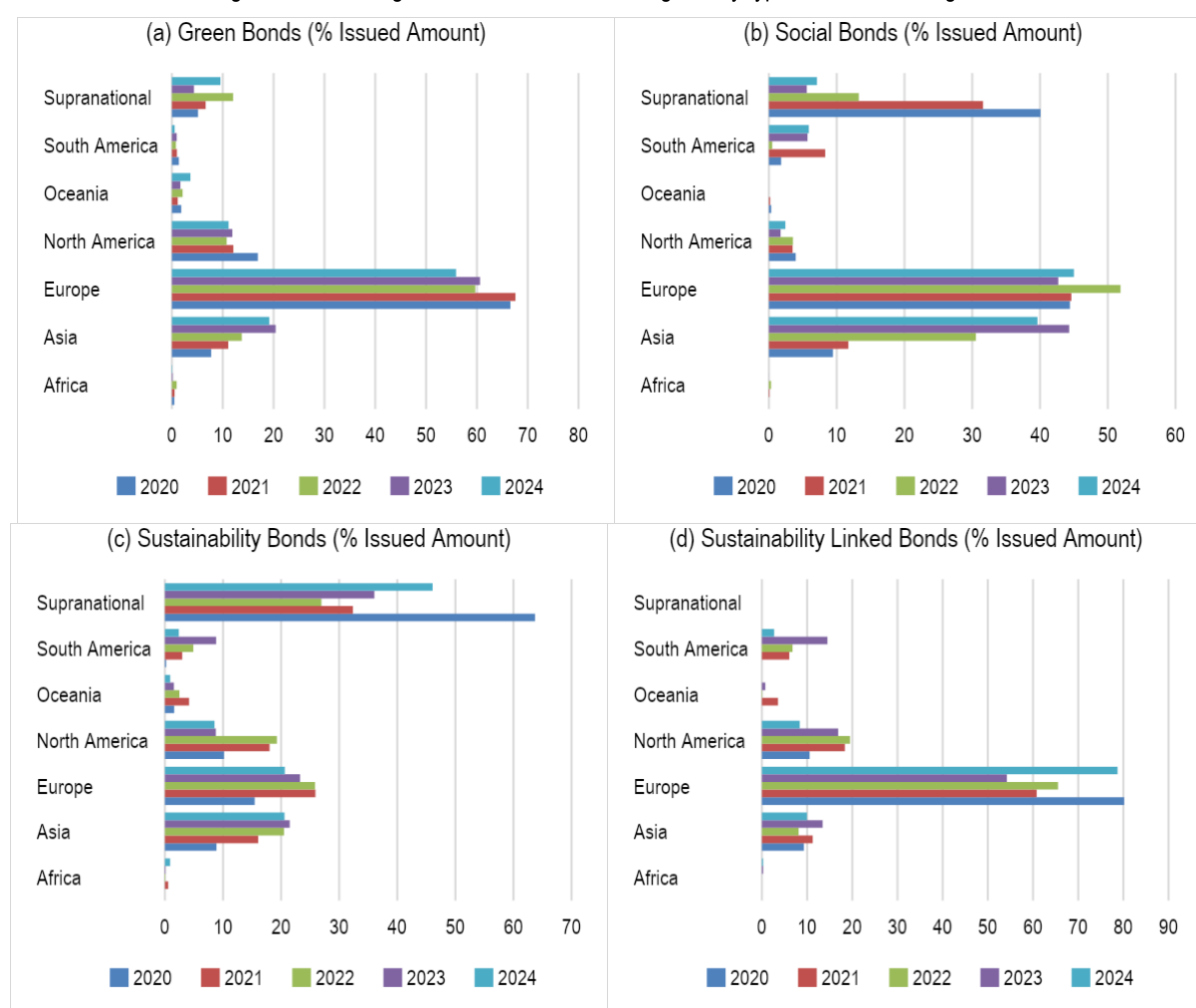
Table 1. All sustainable bonds issued, Billion USD, by regions, 2000 to 2024

Regions	Africa	Asia	Europe	North America	Oceania	South America	Supranational
2020	1.103 (0.4)	11.758 (8.25)	247.401 (47.11)	60.142 (11.45)	6.955 (1.32)	6.060 (1.15)	158.710 (30.22)
2021	4.142 (0.4)	125.424 (12.09)	573.176 (55.26)	125.325 (12.08)	17.777 (1.71)	33.101 (3.19)	158.354 (15.27)
2022	4.833 (0.6)	136.956 (17.06)	423.996 (52.82)	96.056 (11.97)	13.407 (1.67)	16.097 (2.01)	111.436 (13.88)
2023	0.997 (0.13)	185.360 (24.15)	380.274 (49.55)	76.001 (9.9)	9.861 (1.28)	33.317 (4.34)	81.596 (10.63)
2024	1.437 (0.26)	122.226 (22.15)	260.179 (47.15)	50.735 (9.19)	13.074 (2.37)	9.941 (1.8)	94.260 (17.08)

Note: Figures in the parenthesis represents percentage of Issued Amount with respect to respective year

Source: International Capital Market Association (ICMA) database, several years

Figure 1. Percentage issued amount across regions by types of bonds during 2020 to 2024



Source: International Capital Market Association (ICMA) database, several years

The regional distribution of four types of bonds from 2020 to 2024 reveals distinct patterns. [Figure 1(a) to 1(d)] Green bonds were predominantly issued in Europe, accounting for 62.07% of the total, followed by Asia (14.42%), North America (12.55%), Supranational entities (7.53%), Oceania (2.07%), South America (0.92%), and Africa (0.43%). In contrast, social bonds saw a more evenly distributed issuance, with Europe leading at 45.72%, followed by Asia (27.12%), Supranational entities (19.52%), South America (4.43%), North America (3.02%), Oceania (0.26%), and Africa (0.14%). Sustainability bonds, however, were led by Supranational entities with a 41.03% share, trailed by Europe (22.22%), Asia (17.50%), North America (12.95%), South America (3.85%), Oceania (2.13%), and Africa (0.41%).

Lastly, sustainability-linked bonds were overwhelmingly dominated by Europe, which accounted for 67.89% of the total issuance, followed by North America (14.73%), Asia (10.40%), South America (7.50%), Oceania (1.46%), and Africa (0.265%). These regional variations highlight the diverse landscape of bond issuance across different markets.

An examination of bond trading activity on Bourse de Luxembourg, Euro MTF, and Lux SE SOL exchanges over a 25-year period (1999-2024) reveals distinct trends and preferences in the green bond market. The Bourse de Luxembourg exchange emerges as the dominant platform, accounting for 74.84% of all bond trades. Green Bonds are the most frequently traded instrument across all three exchanges, indicating their widespread adoption. Remarkably, Sustainable Bonds rank second in trading frequency on the Bourse de Luxembourg and Euro MTF, whereas Social Bonds occupy the second position on Lux SE SOL, suggesting exchange-specific preferences. These findings underscore the importance of considering the unique dynamics and trends on each exchange, providing valuable insights into the evolving landscape of the green bond market (Table 2).

Table 2. Types of bonds listed and traded in the global market by exchange

Types of bonds	Bourse de Luxembourg	Euro MTF	Lux SE SOL	Total
Social Bonds	125 (69.44)	30 (16.67)	25 (13.89)	180 (100)
Green Bonds	1486 (74.08)	432 (21.54)	88 (4.39)	2006 (100)
Sustainability Linked Bonds	39 (41.05)	52 (54.74)	4 (4.21)	95 (100)
Sustainable Bonds	507 (84.36)	87 (14.48)	7 (1.16)	601 (100)
Grand Total	2157 (78.84)	601 (20.85)	124 (4.30)	2882 (100)

Note: Figures in the parenthesis represents percentage value  
 Source: Luxembourg Green Exchange, several years

Table 3 presents the distribution of traded bonds across four categories, revealing a pronounced dominance of Green Bonds in the market. With a significant majority of 69.60%, Green Bonds outweigh other categories, followed by Sustainable Bonds, which account for 20.85% of total traded bonds. Social Bonds and Sustainability Linked Bonds constitute smaller but notable portions, representing 6.25% and 3.30% of total traded bonds, respectively. This hierarchical distribution underscores a clear preference among investors for green bonds, followed by sustainable bonds, social bonds, and sustainability linked bonds. The findings provide valuable insights into market trends and investor preferences in the green bond sector, highlighting the leading role of Green Bonds in the market.

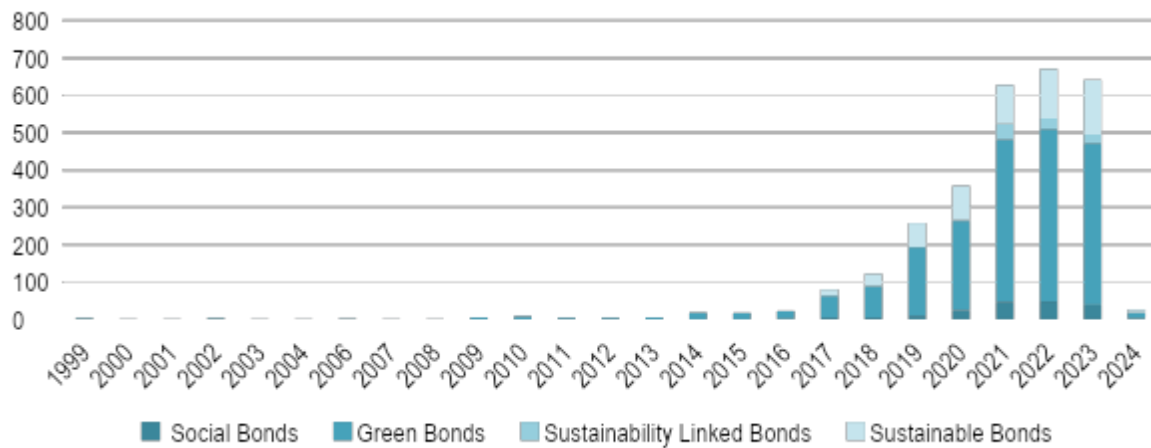
Table 3. Exchange wise traded bonds by different types in the global market

Types of bonds	Bourse de Luxembourg	Euro MTF	Lux SE SOL	Total
Social Bonds	125 (5.80)	30 (4.99)	25 (20.16)	180 (6.25)
Green Bonds	1486 (68.89)	432 (71.88)	88 (70.97)	2006 (69.60)
Sustainability Linked Bonds	39 (1.81)	52 (8.65)	4 (3.23)	95 (3.30)
Sustainable Bonds	507 (23.50)	87 (14.48)	7 (5.65)	601 (20.85)
Grand Total	2157 (100)	601 (100)	124 (100)	2882 (100)

Note: Figures in the parenthesis represents percentage value,  
 Source: Luxembourg Green Exchange, several years

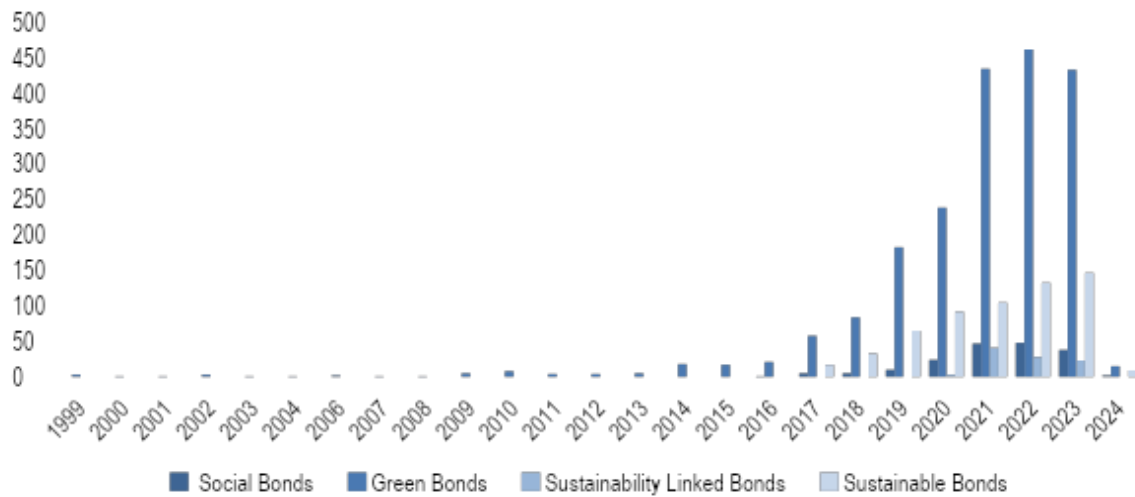


Figure 2. Composition of different types of bonds over time



Source: Luxembourg Green Exchange, several years

Figure 3. Temporal Changes of types of bonds over time

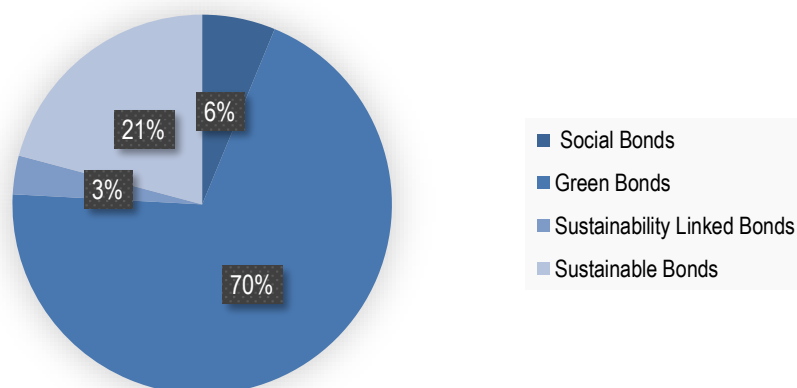


Source: Luxembourg Green Exchange, several years

The temporal dynamics of green bond market trends in the Luxembourg Green Exchange are illuminated by Figure 2 and Figure 3, revealing significant shifts in market share over time. Initially, green bonds were introduced in 1999 but experienced a stagnant market share until 2016, after which they surged in popularity, sustaining growth until 2022. In contrast, sustainable bonds began gaining traction in 2017, steadily increasing their market share until 2023. Social bonds also grew, albeit at a slower rate, between 2017 and 2023. Particularly, the emergence of Sustainability Linked Bonds during the COVID-19 pandemic suggests a potential shift in investor preferences towards environmentally responsible investments during times of global uncertainty. These graphical representations offer valuable insights into the evolving landscape of green bond markets, highlighting trends, patterns, and potential drivers of growth, and underscoring the dynamic nature of the market.

Figure 4 provides a snapshot of the global market share distribution among four types of bonds, revealing a pronounced dominance of Green Bonds and Sustainable Bonds. With a commanding 70% market share, Green Bonds demonstrate widespread adoption and investor preference, while Sustainable Bonds follow closely with 21% of the market share. The combined market share of these two bond types totals 90%, indicating a strong inclination towards environmentally responsible investments in the global bond market. In contrast, Social Bonds and Sustainability Linked Bonds have relatively modest market shares of 6% and 3%, respectively. This concentration of market share among Green Bonds and Sustainable Bonds underscores the growing significance of environmentally focused investments in the global bond market, highlighting a shift towards sustainable finance.

Figure 4. Percentage distribution of Green, Social and Sustainable (GSS) bonds



Source: Luxembourg Green Exchange, several years

Table 4 provides a comprehensive overview of the descriptive statistics for coupon rates of four distinct bond types - Green Bonds, Sustainable Bonds, Social Bonds, and Sustainability Linked Bonds - across three prominent exchanges: Bourse de Luxembourg, Euro MTF, and Lux SE SOL. The statistics encompass the range, average, standard deviation, and coefficient of variation, offering insights into the dispersion and central tendency of coupon rates. Especially, the coefficient of variation, which measures the level of dispersion relative to the mean, is uniformly highest for all bond types on the Bourse de Luxembourg exchange. This suggests that investors may encounter greater variability in returns on bonds traded on this exchange, underscoring the importance of careful consideration and risk assessment.

Table 4. Descriptive statistics of bond coupon by types of bonds traded in Exchange

Exchange	Social Bonds					
	N	Max	Min	Average	StdDev	Coefficient of Variation
Bourse de Luxembourg	103	0.0688	0.0001	0.0180	0.0169	93.79
Euro MTF	26	0.1070	0.0013	0.0557	0.0294	52.82
LuxSE SOL	20	0.1050	0.0285	0.0700	0.0237	33.86
Exchange	Green Bonds					
	N	Max	Min	Average	StdDev	Coefficient of Variation
Bourse de Luxembourg	1152	0.1350	0.0001	0.0268	0.0218	81.55
Euro MTF	375	0.1070	0.0001	0.0362	0.0222	61.39
LuxSE SOL	72	0.1550	0.0001	0.0487	0.0334	68.45
Exchange	Sustainability Linked Bonds					
	N	Max	Min	Average	StdDev	Coefficient of Variation
Bourse de Luxembourg	38	0.065	0.004	0.026	0.020	75.72
Euro MTF	50	0.090	0.009	0.045	0.020	42.90
LuxSE SOL	4	0.051	0.036	0.043	0.008	18.06
Exchange	Sustainable Bonds					
	N	Max	Min	Average	StdDev	Coefficient of Variation
Bourse de Luxembourg	393	0.1350	0.0001	0.0301	0.0239	79.63
Euro MTF	72	0.0950	0.0001	0.0345	0.0190	55.18
LuxSE SOL	5	0.0835	0.0088	0.0400	0.0297	74.09

Source: Luxembourg Green Exchange, several years

Table 5 reveals an intriguing analysis of bond duration, showcasing a notable distinction between bond types and exchanges. Except for Green Bonds, the maximum duration is significantly higher for Sustainable Bonds, Social Bonds, and Sustainability Linked Bonds on the Bourse de Luxembourg Exchange. Conversely, Green Bonds exhibit their maximum duration on the Euro MTF Exchange, indicating a variation in bond duration profiles across different exchanges and bond types. This finding underscores the significance of considering bond duration in investment decisions, as it can substantially impact returns and risk exposure. Investors must carefully evaluate bond duration to optimize their investment strategies and mitigate potential risks. The disparity in bond duration profiles across exchanges and bond types adds a layer of complexity, highlighting the need for thorough analysis and informed decision-making.

Table 5. Range of bond duration (in months) by types of bonds across Exchanges

Duration (in months)	Bourse de Luxembourg			Euro MTF			LuxSE SOL		
	N	Max	Min	N	Max	Min	N	Max	Min
Social Bonds	125	720	24	30	359	33	25	52	11
Green Bonds	1,486	723	5	432	735	23	88	239	11
Sustainability Linked Bonds	39	240	48	52	144	53	4	116	58
Sustainable Bonds	507	600	9	87	602	35	7	175	35
<b>Grand Total</b>	<b>2,157</b>	<b>723</b>	<b>5</b>	<b>601</b>	<b>735</b>	<b>23</b>	<b>124</b>	<b>239</b>	<b>11</b>

Source: Luxembourg Green Exchange, several years

Table 6 reveals that the Bourse de Luxembourg Exchange facilitates bond trading in a diverse range of 27 currencies, with the top 10 currencies driving the majority of transactions. A notable concentration of trading activity is observed in the top three currencies, namely the EUR, USD, and SEK, which collectively account for a substantial 73.89% market share. The EUR emerges as the dominant currency, commanding a 53.31% share, followed by the USD at 14.65%, and the SEK at 5.93%. This significant concentration of trading activity in these three currencies underscores their importance in global bond markets and highlights the Bourse de Luxembourg Exchange's pivotal role in facilitating international investment flows. The findings suggest a high degree of reliance on these currencies for bond trading, reflecting their widespread acceptance and use in global financial markets.

Table 6. Top 10 currency used by types of bonds trading in Bourse de Luxembourg

Currency	Social Bonds	Green Bonds	Sustainability Linked Bonds	Sustainable Bonds	Total
EUR	100	830	35	185	1150 (53.31)
USD	11	188	2	115	316 (14.65)
SEK	5	109	2	12	128 (5.93)
GBP	2	45	0	18	65 (3.01)
NOK	1	37	0	17	55 (2.55)
CAD	3	33	0	13	49 (2.27)
UYU	0	24	0	23	47 (2.18)
AUD	0	26	0	17	43 (1.99)
BRL	1	23	0	15	39 (1.81)
MXN	0	23	0	13	36 (1.67)
<b>Grand Total</b>	<b>125</b>	<b>1486</b>	<b>39</b>	<b>507</b>	<b>2157 (100)</b>

Note: Figures in the parenthesis represents percentage value. Source: Luxembourg Green Exchange, several years

Table 7. Top 10 currency used by types of bonds trading in Euro MTF

Currency	Social Bonds	Green Bonds	Sustainability Linked Bonds	Sustainable Bonds	Total
USD	17	178	29	41	265 (44.09)
EUR	2	187	23	39	251 (41.76)
AUD	1	13	0	4	18 (2.96)
GBP	0	14	0	1	15 (2.50)
SEK	0	8	0	1	9 (1.50)
CAD	0	8	0	0	8 (1.33)
COP	2	6	0	0	8 (1.33)
NOK	0	6	0	0	6 (0.99)
MXN	1	2	0	1	4 (0.67)
UYU	1	1	0	0	2 (0.33)
<b>Grand Total</b>	<b>30</b>	<b>432</b>	<b>52</b>	<b>87</b>	<b>601 (100)</b>

Note: Figures in the parenthesis represent percentage value. Source: Luxembourg Green Exchange, several years

Currency preferences for bond trading vary significantly between the Euro MTF and LuxSE SOL exchanges. The Euro MTF Exchange, which utilizes 18 currencies, is dominated by the USD, EUR, and AUD, accounting for 44.09%, 41.76%, and 2.96% of transactions, respectively (Table 7). In contrast, the LuxSE SOL Exchange, which trades in 42 currencies, displays a different hierarchy, led by the EUR (29.03%), USD (25.00%), and INR (11.29%). This disparity highlights the unique currency profiles of each exchange, with the EUR and USD featuring prominently in both, while the AUD and INR emerge as notable third-place currencies on the Euro MTF and LuxSE SOL exchanges, respectively (Table 8).

Table 8. Top 10 currency used by types of bonds trading in LuxSE SOL Exchange

Currency	Social Bonds	Green Bonds	Sustainability Linked Bonds	Sustainable Bonds	Total
EUR	2	29	4	1	36 (29.03)
USD	6	24	0	1	31 (25.0)
INR	6	8	0	0	14 (11.29)
CNY	2	8	0	1	11 (8.87)
GEL	2	3	0	1	6 (4.84)
AMD	0	2	0	2	4 (3.23)
COP	1	1	0	0	2 (1.61)
IDR	1	1	0	0	2 (1.61)
ZAR	1	1	0	0	2 (1.61)
RON	1	1	0	0	2 (1.61)
<b>Grand Total</b>	<b>25</b>	<b>88</b>	<b>4</b>	<b>7</b>	<b>124</b>

Note: Figures in the parenthesis represent percentage value. Source: Luxembourg Green Exchange, several years

An analysis of the top 10 bond-issuing institutions out of 348 reveals a pronounced concentration of market leadership across various bond types. NedWaterBank dominates the Social Bonds segment with a 62.78% market share, while WorldBank leads the green bonds category with a 41.92% share. AEGEA FINANCE emerges as the top issuer of sustainability linked bonds, accounting for 29.47% of the market. Notably, WorldBank also tops the sustainable bonds category with an impressive 85.69% market share, demonstrating its prominence in the market. These findings highlight a clear pattern of market leadership, with a few institutions dominating each bond category. The concentration of bond issuance among these key institutions underscores their significant influence in shaping the global bond market, particularly WorldBank's leadership in both green bonds and sustainable bonds (Table 9).

Table 9. Bond Issuing Institute by type of bonds from Luxembourg Green Exchange

(A) Bond Issuing Institute	Social Bonds	(B) Bond Issuing Institute	Green Bonds	(C) Bond Issuing Institute	Sustainability Linked Bonds	(D) Bond Issuing Institute	Sustainable Bonds
Ned Water Bank	23	WorldBk	437	AEGEA FINANCE	4	WorldBk	384
Mic Smal Med EntBd	19	BEI	68	OrbAdvCorp	4	IntDevAss	24
UE	13	DeutscheBank	61	EQT	3	BNGBank	22
Council Eur DevBk	12	DBahnFinance	55	Henkel AG&Co	3	SGIssuer	19
EBRD	10	KfWA	42	Rexel	3	DevelopBk Japan	14
CentAmBk Ecolnte	8	CredAgr CIBFiSol	41	TDCNetAS	3	BEI	13
Commun FrDeBelg	8	NedWaterBank	35	A2A	2	WorldBk FRN	13
CAIFRAFIN LOC	7	MicSmal MedEntBd	35	Hera	2	NatBank Canada	13
Citigroup GlobMa	7	NatixisStructl	35	Klabin Austria	2	ActionLoge Serv	7
AfDB	6	EBRD	32	Rumo Luxembourg	2	Goldman SFCI	6
Sub Total Top 10 Issuer	113 (62.78%)	Sub Total Top 10 Issuer	841 (41.92%)	Sub Total Top 10 Issuer	28 (29.47%)	Sub Total Top 10 Issuer	515 (85.69%)
Grand Total 348 Issuer	180 (100%)	Grand Total 348 Issuer	2006 (100%)	Grand Total 348 Issuer	95 (100%)	Grand Total 348 Issuer	601 (100%)

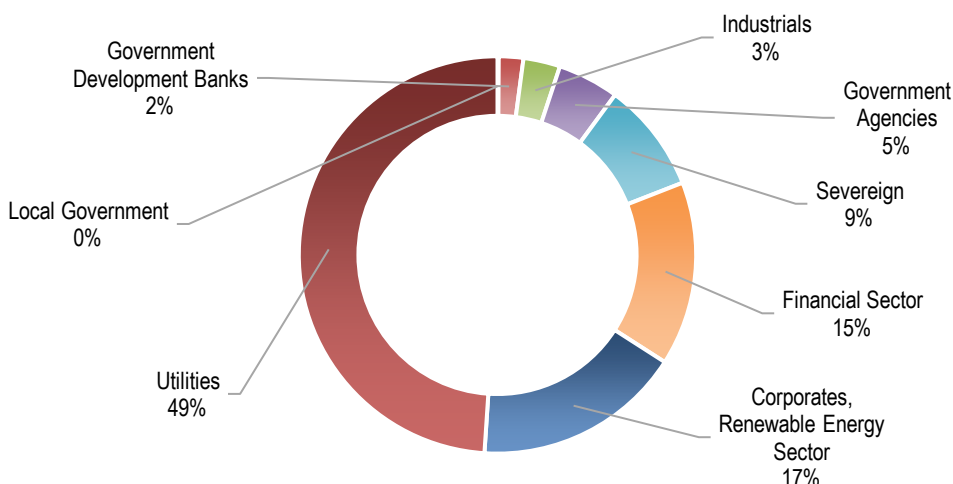
Note: Figures in the parenthesis represent percentage value. Source: Luxembourg Green Exchange, several years

## (B) Indian Sustainable Bond Market

### (B1) Indian Green, Social, and Sustainability bond Market

The India Sustainable Debt State of the Market 2021 report showcases a remarkable year for thematic debt in India, characterized by significant growth and diversification in the sustainable debt market. In 2021, the Indian Green, Social, and Sustainability (GSS) market reached a total size of USD 19.5 billion, with green bonds leading the way at USD 18.3 billion. It also highlights notable growth in the Indian Social and Sustainability bond market, which reached USD 1.1 billion in 2021, indicating increasing interest in these segments. Additionally, USD-denominated issuance dominated the market, accounting for 87% of the cumulative amount. GSS debt issuance in India surged by 585% to USD 7.5 billion in 2021, driven primarily by green-labelled instruments, which grew by 484% year-on-year to USD 6.4 billion. The report also notes the emergence of new products, including social bonds, sustainability bonds, and sustainability-linked bonds, with notable issuances in 2021. The market composition analysis reveals that the private sector, led by non-financial corporates, government-backed entities, and financial corporates, accounts for three-quarters of the cumulative labelled bond volume. Corporates have maintained a consistent presence in the market since 2016, driving growth and innovation in the sustainable debt market (Figure 5).

Figure 5. Green bond amounts issued in India by type of issuer



Source: World Bank with data from Bloomberg<sup>2</sup>, excerpted from Hussain & Dill (2023)

India's green bond market has witnessed remarkable growth since 2015, with financial institutions and government agencies actively utilizing this instrument. As of February 2023, total Indian green bond issuances have reached \$21 billion, driven primarily by the private sector, which accounts for 84% of this growth. The Greenko Group has emerged as the largest green bond issuer in India, channelling proceeds towards funding various renewable energy projects, including hydro, solar, and wind power initiatives across Indian states. In a significant development, local governments in India have begun to participate in the green bond market, with Ghaziabad Nagar Nigam and Indore Municipal Corporation issuing green bonds in 2021 and 2023, respectively. This growing participation underscores India's commitment to sustainable development and renewable energy initiatives.

India has established itself as a leader in the green bond market among Asian emerging markets, excluding China, with a total issuance of \$21 billion. This achievement highlights India's dedication to sustainable development and climate action. The Government of India's recent entry into the green bond market is poised to catalyze further investments in green and climate-friendly projects, supporting India's transition towards a green, resilient, and inclusive development trajectory, aligned with its environmental and sustainability goals.

### (B2) Green Debt Securities

The Securities and Exchange Board of India (SEBI) has launched Green Debt Securities (GDS) as a pioneering financial instrument to support sustainable development and environmentally friendly projects. GDS enables companies and governments to raise capital for initiatives with positive environmental or climate benefits, appealing to investors seeking to make a positive impact. SEBI is actively promoting GDS in India to encourage responsible investment and facilitate a transition to a greener economy. To ensure transparency and accountability, SEBI has established guidelines and regulations for GDS issuance and listing, including disclosure requirements for environmental and social impact information. SEBI's GDS initiative harnesses the power of capital markets to support India's sustainable development goals. By providing a platform for environmentally friendly projects, SEBI aims to attract socially responsible investors and promote a greener economy. SEBI's framework for GDS ensures market integrity through comprehensive guidelines and regulations, including robust disclosure requirements. This enables investors to make informed decisions and supports the growth of a transparent and credible GDS market in India, promoting sustainable development and responsible investment.

#### Some key statistics related to India's Green Debt Securities

India's Green Debt Securities (GDS) market has experienced significant growth, with 16 issuances raising over ₹10,000 crore (approximately \$1.3 billion) as of March 2023. This milestone demonstrates the increasing importance of sustainable finance in India. The Indian Renewable Energy Development Agency (IREDA) made a notable impact with the largest GDS issuance to date in 2022, generating ₹3,000 crore (approximately \$390

<sup>2</sup> [https://blogs.worldbank.org/climatechange/india-incorporates-green-bonds-its-climate-finance-strategy#:~:text=Indian%20green%20bond%20issuances%20have,total%20\(see%20Figure%201\),&text=The%20largest%20green%20bond%20issuer,with%20its%20green%20bond%20proceeds](https://blogs.worldbank.org/climatechange/india-incorporates-green-bonds-its-climate-finance-strategy#:~:text=Indian%20green%20bond%20issuances%20have,total%20(see%20Figure%201),&text=The%20largest%20green%20bond%20issuer,with%20its%20green%20bond%20proceeds)

million). This achievement highlights the leadership of public sector entities like IREDA and the National Bank for Agriculture and Rural Development (NABARD) in promoting sustainable development (Table 10).

Table 10. SEBI Green Debt Statistics as on 30/11/2023

Sr no	Issuer	Date of Issue	Date of Maturity	Amount (Rs. In Crores)	Coupon (%)	Tenure	ISINs
1	L&T Infrastructure Finance Company Ltd	29/06/2017	18/11/2024	667.00	7.59%	7.39	INE691I07DZ9
2	Tata Cleantech Capital Limited	18/12/2018	18/12/2023	180.00	8.74%	5.00	NE857Q07216
3	Indian Renewable Energy Development Agency Limited	03/01/2019	03/01/2029	275.00	8.51%	10.01	NE202E07260
4	Indian Renewable Energy Development Agency	17/01/2019	17/01/2029	590.00	8.47%	10.01	INE202E07278
5	Ghaziabad Nagar Nigam *	31/03/2021	06/04/2025 06/04/2026 06/04/2027 06/04/2028 06/04/2029 06/04/2030 06/04/2031	150.00	8.10%	4.02 5.02 6.02 7.02 8.02 9.02 10.02	NE0GVF24014 INE0GVF24022 INE0GVF24030 INE0GVF24048 INE0GVF24055 INE0GVF24063 INE0GVF24071
6	Yarrow Infrastructure Private Limited	01/07/2021	01/07/2024	581.00	6.49%	3.00	INE001W07011
7	Priapus Infrastructure Limited	01/07/2021	01/07/2024	16.00	6.49%	3.00	INE964M07011
8	Rattanindia Solar 2 Private Limited	01/07/2021	01/07/2024	227.00	6.49%	3.00	INE935V07012
9	Malwa Solar Power Generation Private Limited	01/07/2021	01/07/2024	197.00	6.49%	3.00	INE999X07014
10	Citra Real Estate Limited	01/07/2021	01/07/2024	19.00	6.49%	3.00	INE969M07010
11	Sepset Constructions Limited	01/07/2021	01/07/2024	197.00	6.49%	3.00	INE961M07017
12	Fermi Solarfarms Private Limited	28/02/2022	28/02/2025	337.00	6.75%	3.00	INE404X07015
13	Clean Sustainable Energy Private Limited	28/02/2022	28/02/2025	334.00	6.75%	3.00	INE00JT07017
14	Avaada Sataramh Private Limited	28/02/2022	28/02/2025	270.00	6.75%	3.00	INE0CSU07013
15	Avaada Solarise Energy Private Limited	28/02/2022	28/02/2025	499.00	6.75%	3.00	INE07H107012
16	Indore Municipal Corporation*	20/02/2023	20/02/2026 20/02/2028 20/02/2030 20/02/2032	244.00	8.15%	3.00 5.00 7.00 9.00	INE00QS24019 INE00QS24043 INE00QS24027 INE00QS24035
Total				4,783.00			

Note : \*Also considered under Municipal Bond Issuance Data.

Source: SEBI Green Debt Statistics, as on 30/11/2023

The GDS market has funded a diverse range of green projects, including renewable energy, energy efficiency, sustainable agriculture, and water management. This demonstrates the potential of GDS to support India's transition to a low-carbon economy and achieve its sustainable development goals. The emergence of SEBI GDS has been a significant milestone for sustainable finance in India, raising awareness about the importance of environmental and social responsibility in investment decisions. As the GDS market continues to evolve, it is

expected to play a crucial role in supporting India's sustainable development goals, with growing investor interest and government support driving further growth and innovation.

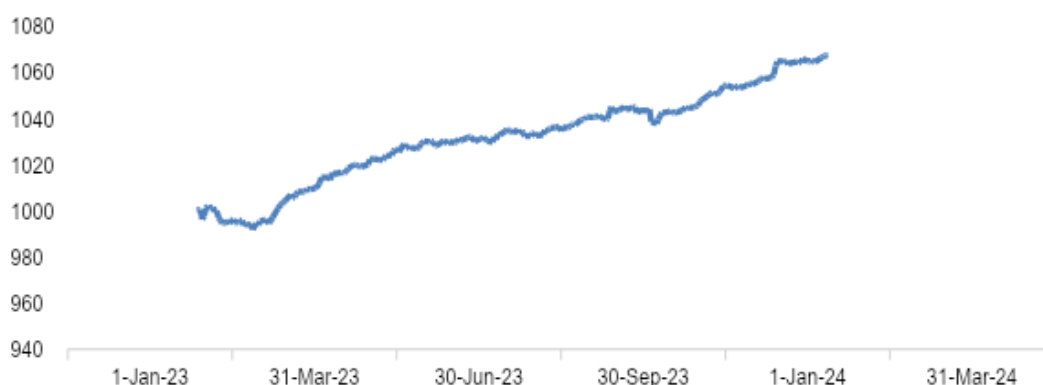
### Contribution by Indian companies in Green Bonds

The India Sustainable Debt State of the Market 2021 report reveals that green bonds are the preferred choice among Indian issuers, with 26 out of 29 issuers having issued at least one green debt instrument since 2015. Renewable energy projects have dominated the use of proceeds, accounting for 89% (USD 16.4 billion) of the total USD 18.3 billion raised through labelled green instruments. Especially, Adani Green Energy's USD 1.35 billion green bond transaction stands out as the largest deal, with funds earmarked for a hybrid portfolio of solar and wind power projects.

Non-financial corporates have emerged as the largest issuer type by volume (USD 12.6 billion) and number of deals (40 out of 77). Indian companies like Adani Green Energy, Hero Future Energies, ReNew Power, Tata Cleantech Capital, and Azure Power have successfully raised significant capital through green bonds to finance renewable energy projects and sustainable initiatives.

The emergence of sustainability-linked bonds (SLBs) in the Indian market, with three such bonds issued by the end of 2021, totalling USD 1.2 billion. Furthermore, companies like Adani Electricity, UltraTech Cement, JSW Steel, National Skill Development Corporation, and FCDO have explored innovative debt instruments, including SLBs and skill impact bonds, to support their sustainability goals. These companies have set Key Performance Indicators (KPIs) to reduce carbon emissions and increase renewable energy sources, linking bond performance to these targets.

Figure 6. Daily closing data movement for NIFTY India Sovereign Green Bond, Jan 2028



Source: NSE Historical data

As of December 31, 2023, an investment of Rs. 1000 has yielded a notable return, with an average yield of 7.21%, a quarterly return of 2.16%, and a half-yearly return of 3.49%. The data reveals a gradual upward trend, indicating consistent and positive performance over time, suggesting a promising outlook for the investment with returns increasing steadily.

Figure 7: Daily closing data movement for NIFTY India Sovereign Green Bond, Jan 2028



Source: NSE Historical data



The Nifty India Sovereign Green Bond Jan 2033 Index provides investors with a transparent and efficient way to track the performance of rupee-denominated sovereign green bonds issued by the Government of India. With a base value of Rs. 1000, the index has delivered impressive returns, including an average yield of 7.31%, a quarterly return of 1.97%, and a half-yearly return of 3.04% as of December 31, 2023. This makes it an attractive option for investors seeking exposure to India's green bond market and contributing to the country's sustainable future.

## Conclusion

India's sustainable debt market is poised for continued growth, driven by supportive government policies and increasing investor demand. While green bonds currently dominate the market, green finance in India remains in its early stages of development. To contextualize India's progress, a benchmarking study was conducted to compare its green bond market with global counterparts. The study analysed listing and trading data across select international markets, providing valuable insights into India's relative position and potential for further growth in the global green finance landscape.

The global green bond market is led by green bonds, which have captured the largest market share, followed closely by sustainable bonds. The Luxembourg Green Exchange stands out for its diverse offerings, boasting the widest range of bonds with varying coupon rates and maturity durations. In India, the private sector dominates the sustainable bond market, holding an impressive 84% market share. Key players like Greenko Group, Ghaziabad Nagar Nigam, and Indore Municipal Corporation are pioneering green bond issuance. Additionally, companies such as Adani Green Energy, Hero Future Energies, and ReNew Power are leveraging green bonds to finance renewable energy projects and sustainable initiatives.

However, despite its growth, India's green bond market faces significant challenges that hinder its full potential. Key obstacles include the absence of a unified framework for green bonds, insufficient investor awareness, and inadequate disclosure and reporting standards. To address these gaps, India's sustainable finance sector requires enhanced standardization, transparency, and policy alignment with national and global best practices. By bridging these gaps, India can unlock the true potential of its green bond market, fostering a more robust and sustainable finance ecosystem that supports the country's environmental and economic goals.

## Credit Authorship Contribution Statement

The author takes full responsibility for this research paper, encompassing all aspects of the project, including conceptualization, data curation, formal analysis, investigation, methodology, project administration, resources, software, supervision, validation, visualization, and writing. This includes originating the research idea, collecting, and analysing data, overseeing the project timeline and resources, and composing and revising the manuscript for publication. The author assumes sole responsibility for the entirety of the project, ensuring the accuracy, reliability, and quality of the research and its findings.

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## Conflict of Interest Statement

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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