



The Role of Green Bonds in Financing Renewable Energy Projects: The Case of Europe

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Abstract :

This study aims to highlight the role of green bonds in financing renewable energy projects within the European Union and to assess their effectiveness in supporting the transition toward a low-carbon economy. Through a descriptive-analytical approach covering the period 2014–2023, the research finds that a significant share of green bond issuances in Europe has been directed toward clean energy projects, particularly in the solar and wind sectors. The results indicate that countries with mature financial markets, such as Germany, France, and the Netherlands, have led in leveraging green bonds, supported by robust regulatory frameworks like the EU Taxonomy and the European Green Deal. Green bonds serve to bridge the financing gap between capital providers and environmentally sustainable projects, accelerating the energy transition and contributing to the EU's climate and sustainability goals.

Key Words: Green Bonds, Renewable Energy, Sustainable Finance, European Union, Low-Carbon Economy.

JEL Classification : Q42, Q56, G12

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Introduction:

As the world faces accelerating environmental changes, efforts by various countries continue to address the adverse impacts of climate change. These impacts—**rising temperatures, droughts, wildfires, and floods—**have negatively affected ecosystems and human health. At the same time, the depletion of non-renewable energy sources and the harmful consequences of their excessive and unsustainable consumption have underscored the urgent need to transition toward renewable energy.

This transition, however, requires several key enablers, **chief among them being** adequate financing and advanced technologies that can make renewable energy more efficient and cost-competitive compared to traditional fossil fuels.

In response, countries across the globe, particularly within the European Union, have pursued innovative solutions to reduce the effects of climate change on both the economy and society. These efforts aim to promote environmental sustainability and



safeguard the rights of future generations. One of the most prominent financial instruments to emerge from this movement is the green bond, which focuses on environmentally conscious investments and provides the necessary financial resources to support clean and sustainable projects, **especially** in the renewable energy sector.

Europe has been at the forefront of promoting green finance by encouraging investments in green energy sources such as solar, wind, hydro, and bioenergy. Through supportive financial and regulatory programs, green bonds have played a critical role in accelerating the shift away from fossil fuels and toward a low-carbon, sustainable energy future.

- **Main Question:** Based on the aforementioned context, the following research question is proposed: **To what extent have Green Bonds contributed to financing Renewable Energy projects in Europe during the period 2014–2023?**
- **Hypothesis:** To answer this central question, the study tests the following hypothesis:
 - Green bonds have significantly contributed to financing environmentally friendly renewable energy projects, aiming to achieve a low-carbon economy and supporting Europe's transition away from traditional energy sources.
- **Objectives:** This study aims to clarify the following:
 - The concept of green bonds as an innovative financial mechanism designed to promote environmental sustainability;
 - The concept of renewable energy and its primary sources;
 - The European experience in financing renewable energy projects, and the factors behind its leadership in both green bond issuance and renewable energy deployment.
- **Methodology:** To answer the main research question and verify the hypothesis, the study adopts a **descriptive-analytical methodology**. It presents and analyzes various aspects related to green bonds and renewable energy in Europe, highlighting the region's production capacity across different renewable sources. The study also examines the volume of green finance directed toward clean energy investment through green bonds, and identifies key success factors that have made Europe a global leader in sustainable finance.

I. Conceptual Framework of Green Bonds:

1. Green Bonds Definition:

At their core, green bonds are debt securities specifically earmarked to finance projects or activities that have positive environmental or climate benefits. Unlike traditional bonds, which may fund a wide range of projects without regard to their environmental impact, green bonds are issued explicitly to promote environmental sustainability. This distinction is fundamental to understanding the role and function of green bonds within the broader context of sustainable finance.

The very first green bond was issued in 2007 with the AAA-rated issuance from multilateral institutions European Investment Bank (EIB) and World Bank. The



market began to grow significantly in 2014, and since then, each year has closed at record all-time. (Smith, Xuan, & Thomas, 2023). Since then, the green bonds market has experienced exponential growth, driven by increasing investor demand for socially responsible investments and the urgent need to address climate change. Today, green bonds represent a significant segment of the global bond market, with issuances spanning various sectors and geographies.

- **Regulatory definition:** Bond marketed as environmentally sustainable means a bond whose issuer provides investors with a commitment or any form of pre-contractual claim that the bond proceeds are allocated to economic activities that contribute to an environmental objective as per Art. 2 of the EU Green Bond Regulation. (Platform ON Sustainable Finance, EU, 2025)
- **Market definition:** Bond instrument where the proceeds or an equivalent amount will be exclusively applied to finance or re-finance, in part or in full, new and/or existing eligible Green Projects, the greenness of the bond is self-defined. (ICMA, 2022)

Fig.1 «The Green Bonds milestones»



Source: Climate Bond Initiatives 2025.

2. Types of green bonds:

The Climate Bonds Initiative (CBI) distinguishes four categories of green bonds: (Dalal, Mehmet, Mahmoud , & Tochukwu, 2018)

- Green use of bond proceeds: A debt obligation with recourse to the issuer that ring-fences proceeds in a subaccount to ensure traceability;
- Green use of proceeds revenue bonds: An obligation without recourse to the issuer; recourse is to the financial flows arising from the project in which the proceeds of the issue of the bond are invested;
- Green project bonds: A project bond with direct exposure to the risk of the project without recourse to the issuer; proceeds are allocated to one or more specific projects;
- Green securitized bonds: A bond collateralized by one or more specific eligible projects and assets.

The CBI also distinguishes labelled green bonds from unlabeled ones. Labelled green bonds are bonds whose proceeds are earmarked for green projects and designated accordingly (CBI 2016). Unlabeled green bonds meet certain criteria, such as investing in projects with lower CO2 emissions, but do not meet all the



characteristics of green bonds, such as the segregation of funds and direct financing of green projects.

3. Advantages and disadvantages of green bonds as cited by investors and issuers: (OECD, 2017)

3.1. For Investors:

a. Advantages:

Commonly cited:

- Investors can balance risk-adjusted financial returns with environmental benefits;
- Satisfies environment, social and governance (ESG) requirements and green investment mandates;
- Improved risk assessment in an otherwise opaque fixed income market through use of proceeds reporting;
- Potential use of pure-play, project and asset-backed securities as instruments to actively hedge against climate policy risks in a portfolio that includes emissions-intensive assets;
- Recognized by the UNFCCC as non-state actor “climate action”.

Infrequently cited

- Engagement and private dialogue with issuers on ESG topics related to green bond issuance results in information that enhances credit analysis, through more comprehensive credit profiles of borrowers;
- Added transparency of use of proceeds and reporting requirements provides informational advantage otherwise unavailable (on spending efficiency, project details and updates, impact performance) which gives green bond investors a significant information advantage;
- Tracking of use of proceeds and reporting leads to improved internal governance structures and a positive feedback loop which improves the overall credit quality of the issuer.

b. Disadvantages:

- Small and nascent (and potentially less liquid) market, small bond sizes;
- Lack of unified standards can create confusion and possibility for reputational risk if green integrity of bond questioned;
- Limited scope for legal enforcement of green integrity;
- Lack of standardization can lead to complexities in research and a need for extra due diligence that may not always be fulfilled.

3.2. For issuers

a. Advantages

Commonly cited:

- Demonstrating and implementing issuer’s approach to ESG issues;
- Improving diversification of a bond issuer’s investor base, thereby expanding funding sources and potentially reducing exposure to bond demand fluctuations;
- Strong investor demand can lead to oversubscription and potential to increase issuance size;



- Evidence of greater proportion of “buy and hold” investors for green bonds which can lead to lower bond volatility in secondary market;
- Reputational benefits (e.g. marketing can highlight issuer’s green credentials and support for green investment);
- Articulation and enhanced credibility of sustainability strategy (putting one’s “money where their mouth is”) leading to enhanced dialogue with investors;
- Access to “economies of scale” as majority of issuance costs are in setting up the processes.

Infrequently cited

- Tracking of use of proceeds and reporting leads to improved internal governance structures, communication and knowledge sharing between project side and treasury side of business;
- For municipalities, a tool to reach constituencies physically located close to the green project they intend to support and provide them with opportunities to invest in programmes that have direct proximal impact.

b. Disadvantages:

Commonly cited:

- Upfront and ongoing transaction costs from labelling and associated administrative, certification, reporting, verification and monitoring requirements (cost estimates vary);
- Reputational risk if a bond’s green credentials are challenged.

Infrequently cited

- Investors may seek penalties for a green default whereby a bond is paid in full but issuer breaks agreed green clauses.

II. Conceptual Framework of renewable energies:

1. Renewable Energy Definition:

Renewable energy is energy derived from natural sources that are replenished at a higher rate than they are consumed. Sunlight and wind, for example, are such sources that are constantly being replenished. Renewable energy sources are plentiful and all around us.

Fossil fuels - coal, oil and gas - on the other hand, are non-renewable resources that take hundreds of millions of years to form. Fossil fuels, when burned to produce energy, cause harmful greenhouse gas emissions, such as carbon dioxide.

Generating renewable energy creates far lower emissions than burning fossil fuels. Transitioning from fossil fuels, which currently account for the lion’s share of emissions, to renewable energy is key to addressing the climate crisis. Renewables are now cheaper in most countries, and generate three times more jobs than fossil fuels. (United Nations, 2025)

The International Renewable Energy Agency (IRENA) has a statutory definition, ratified by 108 members (107 states and the European Union) as of February 2013: “renewable energy includes all forms of energy produced from renewable sources in a sustainable manner, including bioenergy, geothermal energy,



hydropower, ocean energy, solar energy and wind energy.” (IEA, The World Bank, 2014)

2. Renewable energy Segments :Renewable energy sources are numerous and diverse, and they vary depending on their uses. In the following, we will address the most important of these sources: (Rohan & Rajendra, 2022)

2.1. Solar Energy: A solar power system is one that converts the energy of the sun into thermal or electrical energy. Solar energy is the most abundant and cleanest form of renewable energy. This energy can be harnessed by solar technologies to generate electricity, light, and heat water for various commercial and domestic uses.

There are three main ways to harness solar energy:

Solar energy is able to produce and supply an endless supply of energy that can last for thousands of years, eliminating fossil fuel use permanently. It is estimated that the sun can provide more energy than 7500 times the planet's energy needs. Despite all of the benefits of solar energy, it has a limited contribution toward meeting global energy demands because of high installation and storage costs, land use problems, and weather issues.

2.2. Wind Energy: Wind energy is the use of wind to provide electric power using a wind turbine to turn generators. Wind power is an increasingly popular sustainable, renewable energy source that impacts environment much less than burning fossil fuels and other types of renewable sources. With its low carbon footprint and no greenhouse gases emission (GHG), wind energy is among the cleanest forms of energy. Because wind blows everywhere, wind energy is a safe and reliable form of energy. There are some downsides of wind energy such as direct or indirect impact on wildlife especially migratory birds, noise in the surrounding area and disturbance in telecommunication signals etc.

2.3. Bioenergy: Bioenergy refers to electricity and gas that is generated from organic matter, known as biomass. This can be anything from plant and timber to agriculture and food waste and even sewage. Bioenergy includes the production of fuel from organic matter as well. Energy from biomass can be used for electricity, heating, and transportation, and can be replenished anywhere. Around seventy-five percent of the world's renewable energy is composed of biomass energy due to its potential and wide use. Also, it is carbon-neutral, meaning that it adds no net carbon dioxide to the atmosphere. In addition, it reduces the level of trash in the ground by as much as 90 percent by burning solid waste. Biomass fuels, on the other hand, are not completely clean and can also cause deforestation. They are also less efficient than fossil fuels. But proper management and planning of its disadvantages will improve its potential.

2.4. Geothermal Energy: Geothermal energy is a form of renewable energy derived from the earth's core. Radioactive decay and heat generated during planet formation account for the origin of this energy. Earth's core contains rocks and fluids that store thermal energy. It is a reliable, sustainable, and cost-effective source of energy. It is also environmentally friendly with a huge potential to generate electricity. Geothermal energy's main disadvantages are its initial cost and release of greenhouse



gases during energy production. In addition, it is location-restricted, which makes investors think twice.

2.5. Hydropower: Hydropower, or water power, is generated by falling or rapidly moving water. With dams or without dams, hydropower plants fall into two categories. Using hydropower plants with dams, a large amount of water can be stored that can generate a large amount of power. Hydropower plants without dams produce little power and are the ideal means for harvesting power from water. Hydropower is a clean and non-polluting source of energy. It operates at a low maintenance cost. It has a 90 percent conversion rate, making hydropower one of the most efficient sources of energy. Hydroelectricity has a number of disadvantages, including damaging aquatic habitats, emitting carbon and methane, having a high initial cost, and causing floods due to sudden releases of water.

3. Benefits of Renewable Energy Transition: (Cynthia, et al., 2025)

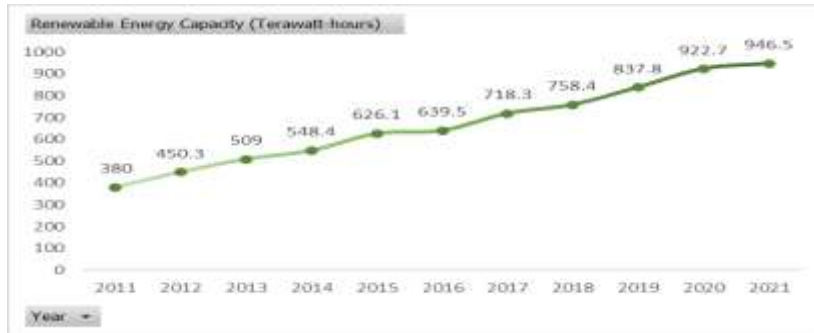
- **Renewable Energy Sources will not run out:** Renewable sources like the sun and wind are naturally replenished and won't deplete over time. This gives them a major advantage over limited fossil fuels;
- **Renewable Energy is Reliable and neutral:** Renewables are less prone to political and market disruptions. A smart energy grid allows stable, peaceful access to power across regions;
- **Renewable Energy is Environmentally Friendly:** They emit very low greenhouse gases and pollutants. This helps combat global warming, climate change, and air pollution;
- **Renewable Energy can Promote public Health:** Cleaner energy means cleaner air and water, reducing diseases. This leads to better public health and lower healthcare costs;
- **Renewable Technologies create lots of jobs:** Renewable industries generate stable, local employment opportunities. They can uplift poor regions and curb urban migration;
- **Renewable Technologies Require less Maintenance Cost:** Renewables have fewer moving parts and less wear and tear. This results in lower maintenance and operational expenses;
- **Renewable Energy Can Reduce Turmoil in Energy Prices:** They insulate economies from oil and gas price shocks. After installation, they offer stable and predictable energy pricing;
- **Renewable Energy Can Increase Countries Economic independence:** Countries can harness domestic sources like sun or wind. This cuts reliance on imported fossil fuels and boosts energy independence;
- **Leftovers Can Be used in Renewable Technologies:** Biomass and similar systems turn organic waste into energy. This reduces landfill use and produces clean energy cost-effectively;
- **Renewable Energy can promote Brand Reputation:** Adopting renewable energy strengthens a company's green image. It appeals to environmentally conscious consumers and investors;



- **Renewable Energy can Encourage Regulatory Compliance:** Renewables help businesses meet environmental laws like the EU's CSRD. This ensures alignment with global climate and ESG reporting standards.

III. Europe's renewable energy production capacity

Fig.2: « European Renewable Energy Production Capacity »



Source:

Prepared by Author based on bp Statistical Review of World Energy 2022.

Table 1: « EU Countries Renewable energy Capacity »

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Austria	6.7	8.5	7.5	13.3	13.4	13.8	12.4	12.8	11.1	10.4	9.2
Belgium	8.2	11.4	10.1	22.4	23.1	19.2	16.9	15.5	13.9	14.1	11.9
Bulgaria	1	2.8	2.1	4.6	4.7	4.6	4.2	3.3	3.2	3.1	2.8
Croatia	0.3	0.7	0.4	3.3	2.9	2.5	2.1	1.8	1.5	1.1	0.9
Cyprus	0.2	0.3	0.3	0.8	0.6	0.5	0.5	0.4	0.4	0.4	0.3
Czech	5.2	6.5	6	8	8	8	7.8	7.7	7.4	7.6	7.3
Denmark	14.2	16	14.8	26	23.4	23.1	20.7	21.8	18.4	18.9	18
Estonia	1.2	1.2	1.4	3.1	2.7	2.1	1.9	1.8	1.5	1.5	1.3
Finland	11.7	12.7	11.6	22.1	19.7	19.4	18.8	16.7	14.5	13.7	12.8
France	19.6	28.6	25.5	62.8	63.3	57.1	49.5	44	39.1	37.5	31.5
Germany	106.	129	121.	217.	231.	220.	204.	194.	167.	168.	141.
Greece	4.1	8	5.7	15.8	14.2	12.1	10.4	9.8	9.4	8.8	7.7
Hungary	2.5	2.6	2.4	6.7	5.3	4.5	3.5	3.3	3	3	2.8
Iceland	4.7	5.3	5.2	5.8	6	6	6	5.2	5.1	5	5.2
Ireland	4.7	5	4.5	10.7	12.6	10.9	9.5	8.2	6.8	7.1	5.7
Italy	37.1	59.2	50.3	71.4	68.8	69.4	65.6	67.7	65.6	63.4	62.1
Latvia	0.2	0.6	0.4	1	1	1.1	1.1	1.1	1	0.9	0.8
Lithuania	0.6	1	0.8	2	2.3	2.1	1.8	1.9	1.6	1.3	1.1
Luxembo	0.2	0.3	0.2	1	0.9	0.7	0.6	0.5	0.3	0.3	0.3
Netherlan	12.3	12.1	12.4	40.1	33	22.7	18.8	17.4	14.6	13.6	11.6
North	1	1	1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1
Norway	1.6	2.3	1.9	12.2	10.3	5.9	4.1	3.1	2.4	2.8	2.5
Poland	10.8	14.6	14.8	27.8	25.3	23.5	19.6	21.6	20.7	20.7	17.7
Portugal	12.6	15.7	13.8	19.2	18	18.6	17	16.7	16.5	15.7	16
Romania	1.6	5.2	2.9	9	9.2	9.1	8.5	9.8	8.9	9.6	6.5



Slovakia	1.2	1.5	1.4	2.7	2.3	2.3	2.2	2.2	2.3	2.2	2
Slovenia	0.3	0.5	0.4	0.6	0.7	0.6	0.5	0.6	0.6	0.5	0.5
Spain	55.6	74.2	66.4	95.8	83.2	73.8	69.8	69.5	68.2	68.9	71.1
Sweden	17.6	21.3	19.4	42.1	39.7	33.5	28.9	29.9	27.1	27.1	22
Switzerla	1.6	2.2	1.9	5.1	4.7	4.2	3.9	3.7	3.2	2.8	2.6
Turkey	5.8	9.8	7.4	62.7	51.5	44.6	38.8	29.9	23.8	16.5	12
Ukraine	0.3	1.3	0.8	11	9.4	5.4	2.6	1.9	1.6	1.7	1.7
United	29.5	48.5	35.9	116.	127.	113.	104.	93	77.6	77.1	58.6
Other	0.1	0.1	0.1	2.8	2.4	2.2	1	0.7	0.4	0.3	0.2
Total	380	509	450.	946.	922.	837.	758.	718.	639.	626.	548.

Source: Prepared by Author based on bp Statistical Review of World Energy 2022.

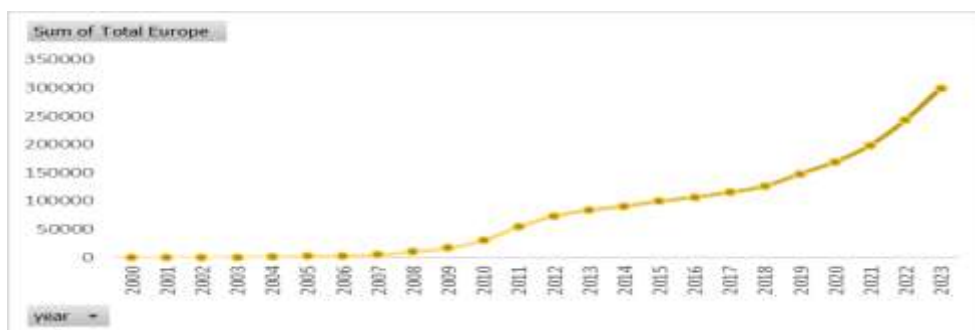
Table 1 and Figure 1 present the evolution of renewable energy production capacity across 33 European countries over a ten-year span. From an economic standpoint, this steady upward trajectory signals a profound structural transformation in the European energy landscape, driven by regulatory mandates, financial innovation, and environmental imperatives. Germany stands out, with its capacity rising from 106.8 GW in 2011 to a peak of 231.8 GW in 2020, before slightly declining to 217.6 GW in 2021. This reduction might be attributed to a shift in policy emphasis or network integration challenges. France and the United Kingdom also demonstrate robust growth, supported by a favorable investment climate and access to green capital instruments.

The economic significance lies in the increasing allocation of capital, both public and private to energy systems that are less susceptible to geopolitical risks and price volatility. This shift reduces external energy dependency and enhances long-term macroeconomic stability. Moreover, countries like Turkey and Sweden exhibit remarkable acceleration, reflecting successful deployment of financing mechanisms such as sovereign green bonds, multilateral development financing, and EU-backed sustainability grants. The distribution of growth also underscores disparities in institutional capacity and financial market maturity within the EU.

The data also suggest a positive feedback loop between green finance and infrastructure development. As the green bond market grows and standardizes, it lowers the cost of capital for clean energy investments, stimulating further expansion. According to the European Investment Bank (EIB), every €1 billion in green bond issuance can unlock up to €4 billion in associated sustainable investments (EIB, 2021). Thus, green bonds act not only as a financing tool but also as a catalyst for economic diversification and technological advancement.



Fig. 3: « EU Solar Energy Capacity»

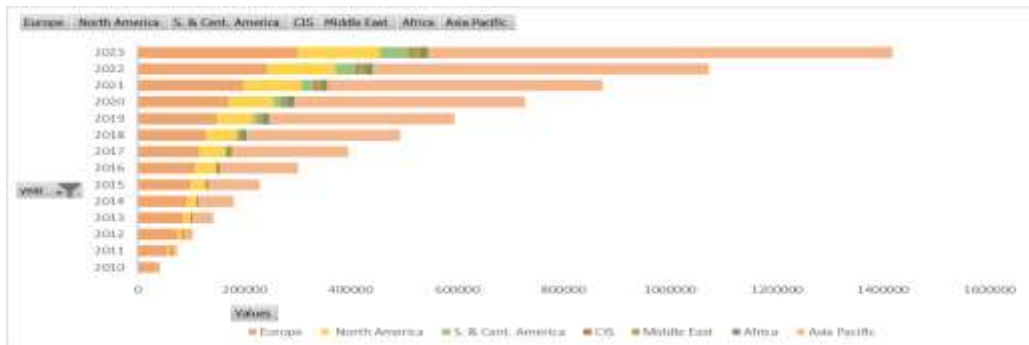


Source: Prepared by Author based on 2024 Energy Institute Statistical Review of World Energy

The exponential increase in solar energy capacity in Europe, from under 200 MW in 2000 to nearly 300,000 MW by 2023, is a testament to the success of energy transition strategies, catalyzed by policy instruments and financial innovations. Economically, this expansion reveals how capital-intensive sectors can scale rapidly when supported by clear regulatory signals, market-based incentives, and favorable financing conditions.

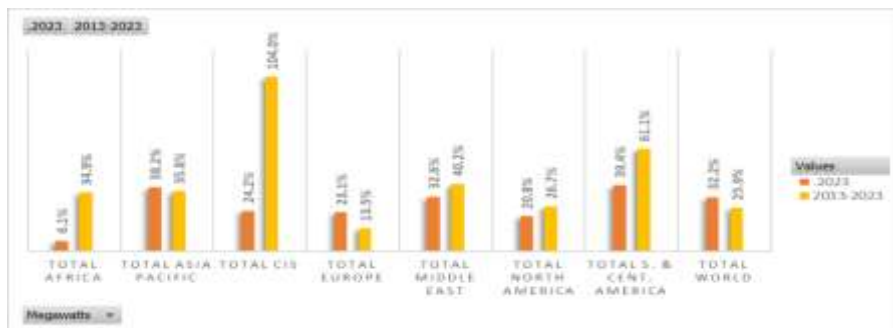
The growth rate accelerates particularly after 2010, aligning with the introduction of national feed-in tariff schemes, tax incentives, and the rise of green bonds. These instruments significantly reduced the weighted average cost of capital (WACC) for renewable projects. Moreover, the economies of scale in photovoltaic (PV) technology and falling module prices reinforced cost-competitiveness, making solar energy not only environmentally preferable but economically rational.

Figure 4 shows that Europe played a pioneering role in solar development, but the data also reveal how its relative share is declining as other regions catch up. Asia-Pacific, in particular, has overtaken Europe in total capacity since 2016, driven by aggressive deployment in China and India. Economically, this reflects shifting patterns of capital flows, labor cost advantages, and domestic content policies in Asia. For Europe, the implication is a pivot toward financial and technological leadership. With a mature market, Europe can export capital via sustainable investment funds and influence global norms via instruments like the EU Green Bond Standard. This transition from quantity to quality supports long-term economic positioning in the green economy.

**Fig.4: « Solar Energy capacity EU vs. World »**

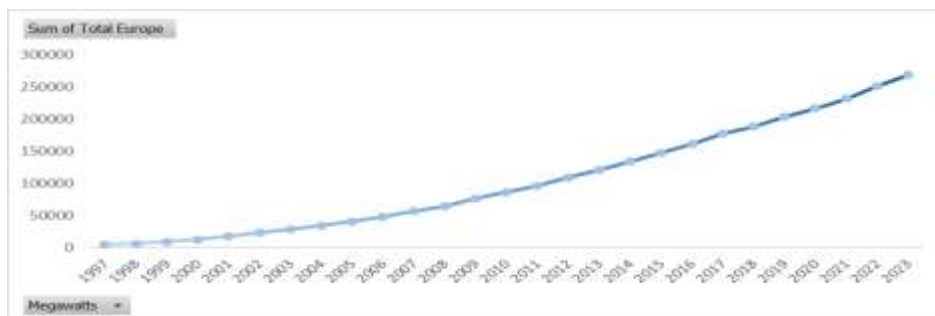
Source: by Author based on 2024 Energy Institute Statistical Review of World Energy

Fig. 5: « Growth Rate of Solar Energy »



Source: by Author based on 2024 Energy Institute Statistical Review of World Energy

From an economic growth theory perspective, regions like Asia-Pacific and South and Central America are in a high-growth phase of technological diffusion, which explains their elevated compound growth rates. In contrast, Europe's lower growth rate (13.5%) indicates a maturing sector where marginal returns from new investments are declining. Nevertheless, such maturity enables financial sophistication. Institutional investors in Europe benefit from stable regulatory environments and investment-grade green bonds, ensuring long-term returns with minimal volatility. The opportunity now lies in reinvesting surpluses into emerging markets or grid modernization projects.

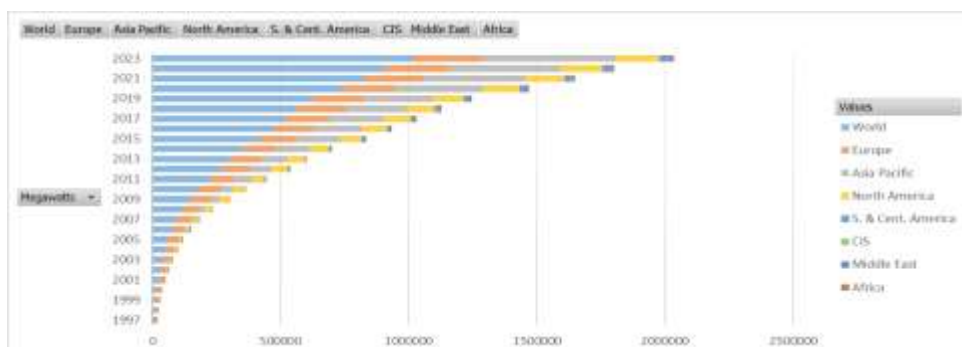
Fig. 6: « EU Wind Energy Capacity »

Source: by Author based on 2024 Energy Institute Statistical Review of World Energy



The consistent increase from 4.8 GW in 1997 to 268.7 GW in 2023 underlines wind energy's central role in Europe's energy mix. The investment profile of wind power—especially offshore—suits long-duration, low-risk capital such as pension funds and insurance companies. Green bonds, particularly those backed by project revenues or sovereign guarantees, have been instrumental in mobilizing such capital. Wind development also boosts economic growth via job creation, local infrastructure development, and supply chain expansion. From a Keynesian perspective, public investment through EU funding has had significant multiplier effects, crowding in private investment.

Fig.7: « Wind energy Capacity EU vs. World »

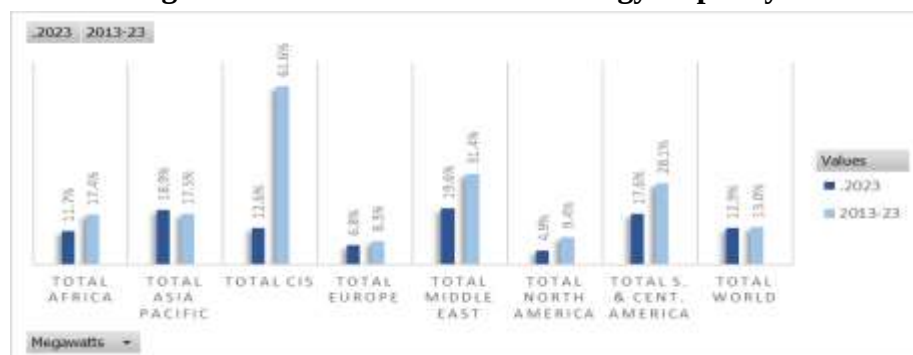


Source: Prepared by Author based on 2024 Energy Institute Statistical Review of World Energy

Global wind growth outpaces Europe due to higher marginal benefits in underdeveloped markets. For Europe, this means a need to transition from basic expansion to enhancing operational efficiency, grid integration, and hybrid models (e.g., wind-plus-storage).

Economically, this could signal a reallocation of capital from capacity building to asset optimization and innovation, supported by new financial tools like green securitization and sustainability-linked bonds.

Fig. 8: «Growth Rate of Wind Energy Capacity »



Source: Prepared by Author based on 2024 Energy Institute Statistical Review of World Energy

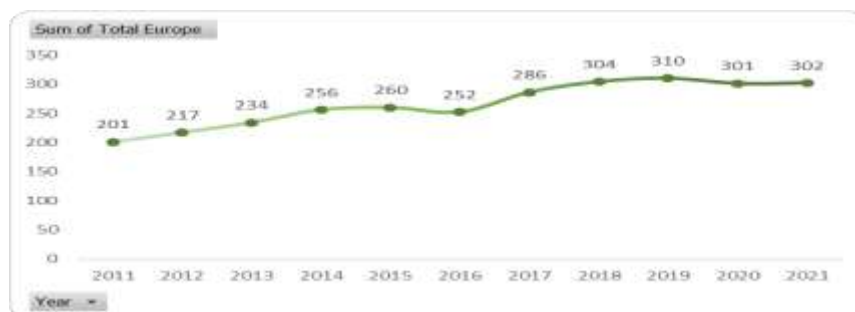
The data reveal that Europe's average growth rate (8.3%) is lower than that of global peers. Asia-Pacific (17.5%) and Latin America (28.1%) reflect significant capital deployment, driven by favorable demographics, policy liberalization, and growing



energy demand. Europe, having already reached high penetration levels, faces integration and intermittency challenges.

To maintain its leadership, Europe must now leverage its mature bond markets to finance R&D, grid upgrades, and cross-border infrastructure. The European Investment Bank and national development banks play critical roles in this transition.

Fig. 9: « EU Biofuels Energy capacity »

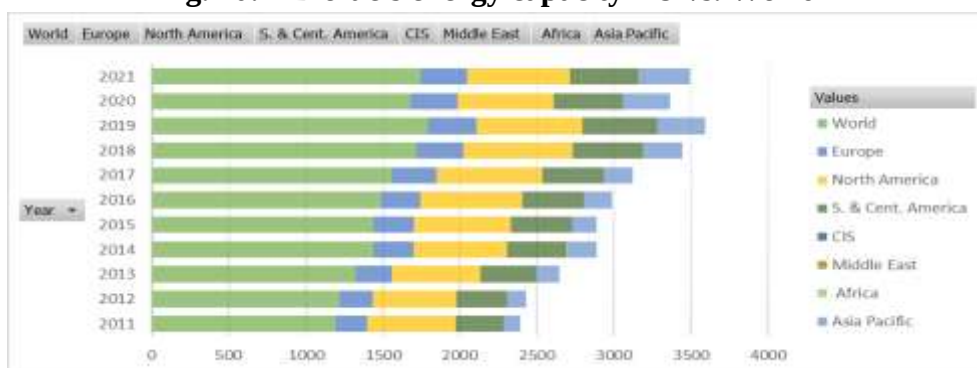


Source: Prepared by Author based on bp Statistical Review of World Energy 2022.

Biofuels capacity in Europe grew from 201 MW in 2011 to 302 MW in 2021, representing modest cumulative growth (~50%) over a decade. This limited expansion can be attributed to biofuels' lower scalability and mixed sustainability credentials compared to wind and solar.

Economically, investors and governments have deprioritized biofuels in favor of electrification and cleaner technologies. Green bond allocations reflect this shift, biofuels typically receive a small share of proceeds due to complex lifecycle emissions and public skepticism. From a policy finance perspective, biofuels remain a nice solution, mostly supported through grants rather than capital market instruments like green bonds.

Fig. 10: « Biofuels energy capacity EU vs. World »



Source: Prepared by Author based on bp Statistical Review of World Energy 2022.

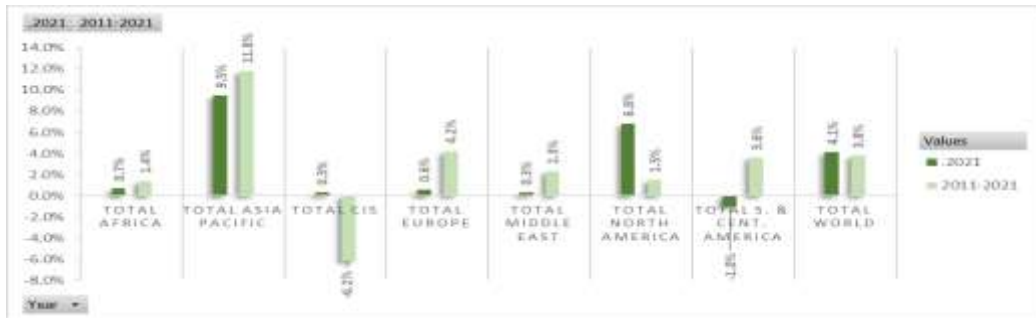
Europe's capacity is stagnant relative to Asia-Pacific and North America, which have expanded more aggressively due to larger agricultural sectors and national mandates (e.g., the U.S. Renewable Fuel Standard, Brazil's ethanol program).

For green bond investors, this implies that biofuels offer lower environmental and financial returns per euro invested compared to utility-scale solar or wind. Moreover,



they carry reputational risks due to deforestation or food-security trade-offs. Therefore, Europe's green bond market, guided by the EU Taxonomy, tends to exclude or limit biofuels financing, unless strict sustainability criteria are met.

Fig. 11: « Biofuels Energy Growth Rate »



Source: Prepared by Author based on bp Statistical Review of World Energy 2022. Europe's growth rate (4.2%) is low compared to Asia-Pacific (11.8%) and even the global average (3.8%). These figures confirm that biofuels are not a priority for green bond mobilization in Europe.

From a green finance standpoint, capital tends to seek projects with higher impact and transparency, which biofuel projects often lack. This also reflects how the EU Taxonomy favors clean electrification over bioenergy due to greater emissions reductions and better integration with smart grids.

IV. The role of green bonds in financing renewable energy projects in Europe:

1. EU Taxonomy Regulation:

The EU Taxonomy Regulation entered into force on 12 July 2020 and establishes an EU-wide classification system for environmentally sustainable economic activities. It serves as a common language and clear definition of what is 'sustainable', based on harmonized criteria at European Union level.

The EU Taxonomy is a cornerstone of the EU's sustainable finance framework and an important market transparency tool. It helps direct investments to the economic activities most needed for the transition to sustainable investments, in line with the European Green Deal objectives.

The EU Taxonomy Regulation interacts with the Corporate Sustainability Reporting Directive (CSRD). Companies that report sustainability statements based on Articles 19a and 29a of the CSRD and the associated ESRS, are also required to provide information on how and to what extent their activities are associated with economic activities that qualify as environmentally sustainable based on the EU Taxonomy in a separate identifiable section of their sustainability statements. (KPMG, 2024)

Under the EU Green Bond Regulation (Regulation (EU) 2023/2631), projects eligible for financing through European Green Bonds must align with the EU Taxonomy Regulation (Regulation (EU) 2020/852), which defines environmentally sustainable economic activities. The eligible project categories include: (European Commission, 2023)

- Climate change mitigation;

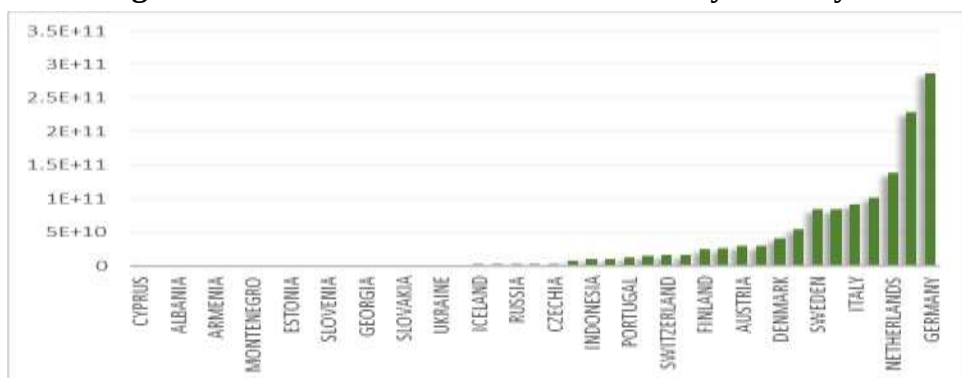


- Climate change adaptation;
- Sustainable use and protection of water and marine resources;
- Transition to a circular economy;
- Pollution prevention and control;
- Protection and restoration of biodiversity and ecosystems.

2. Economic activities and sectors currently covered in EU: Climate Delegated Act and Environmental Delegated Act:

- **Energy:** Renewables, transmission, specific nuclear and natural gas activities (subject to stringent conditions)
- **Forestry:** Afforestation, conservation, forest management, rehabilitation and restoration of forests.
- **Disaster risk management:** Nature-based solutions. Emergency services, flood risk prevention and protection infrastructure.
- **Water supply and sewerage:** Water supply, urban wastewater, sustainable drainage systems (SUDS), phosphorus recovery from wastewater. Water supply, sewerage, waste management and remediation.
- **Transport:** Transitional water and air transport, automotive and rail components. Low emissions, transitional alternatives until 2025, infrastructures.
- **Services** Sale of spare parts and second-hand goods. Preparation for reuse of end-of-life products and product components, marketplace for the trade of second-hand goods for reuse.
- **Buildings:** Construction and renovations, demolition and wrecking, maintenance of roads and motorways, use of concrete in civil engineering. Construction, energy efficiency measures and renovations.
- **Manufacturing:** Plastic packaging goods, electrical and electronic equipment, pharmaceuticals. Enabling technologies, heavy industry (transitional).
- **Information & Communication Technology (ICT) and professional activities:** Software and consultancy IT/OT (information/operational technologies) data-driven solutions.

Fig. 12: « EU Green Bonds Amount Issued by Country »



Source: Prepared by Author based on Climate Bonds Initiative 2024.

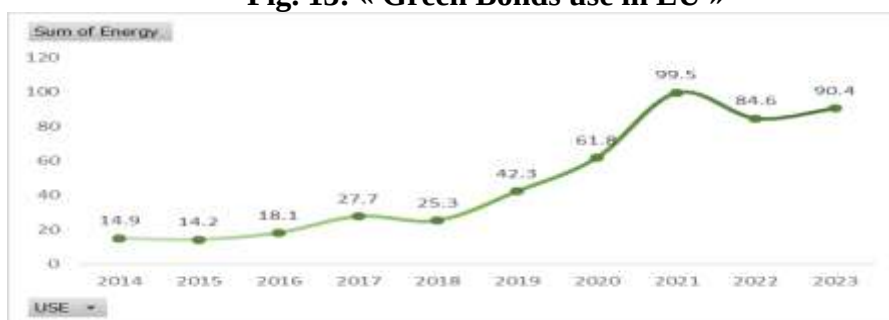
This table provides direct insight into how various European economies are leveraging green bonds to finance renewable energy. Germany (\$287B), France



(\$228B), and the Netherlands (\$138B) are the leading issuers, highlighting their robust capital markets and proactive climate finance strategies.

These volumes are not just indicative of issuance; they reflect a country's ability to attract investment capital for large-scale renewable energy deployment. Germany's volume aligns with its Energiewende policy, while France has been active in issuing sovereign green bonds since 2017. This financial activity enables these states to accelerate their energy transitions without putting excessive pressure on public budgets. Smaller issuers such as Lithuania and Slovakia show that even emerging EU economies are tapping into green bond markets to meet their climate goals. The spread of issuance across the continent indicates that green bonds are becoming a key instrument of energy policy financing, aligned with the EU's long-term net-zero ambitions and Taxonomy regulation.

Fig. 13: « Green Bonds use in EU »

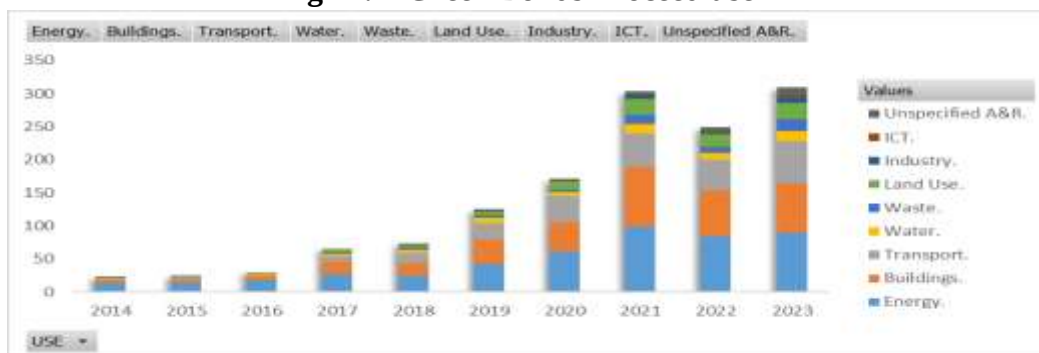


Source: Prepared by Author based on Climate Bonds Initiative 2024.

The continuous growth in green bond allocations for energy—from \$14.9B in 2014 to \$90.4B, in 2023 demonstrates the deepening reliance on bond markets to fund Europe's renewable energy transformation.

This increasing trend corresponds with EU-level strategies such as the European Green Deal and Fit for 55. The spike after 2020 also reflects COVID-19 recovery plans, where green bonds became tools for countercyclical investment in clean energy infrastructure. This not only provided economic stimulus but also redirected structural capital toward low-carbon growth, consistent with Keynesian fiscal stimulus logic combined with sustainable finance policy.

Fig 14: « Green Bonds Proceed use »

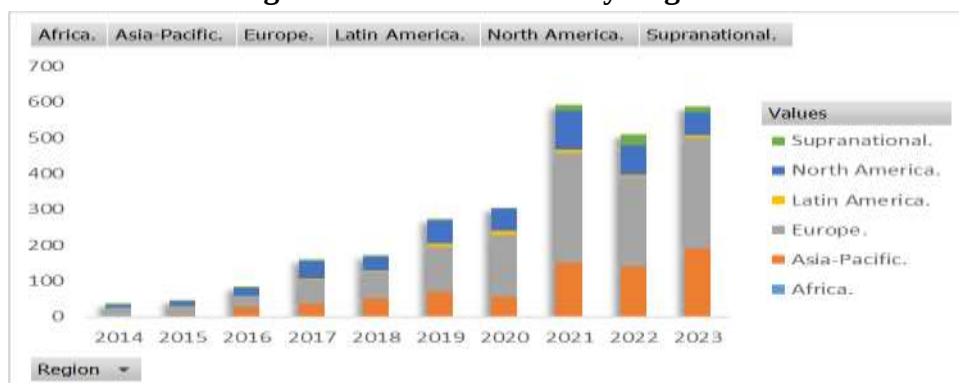


Source: Prepared by Author based on Climate Bonds Initiative 2024.



This table shows the diversification of green bond spending across sectors, with energy consistently being the largest beneficiary. By 2023, €90.4B was directed to energy, while buildings (€74.1B) and transport (€64.2B) followed closely. The strategic allocation toward energy confirms that green bonds are effectively mobilized to finance renewable energy projects including wind farms, solar PV infrastructure, etc. This validates that green bonds are a financial mechanism capable of scaling up Europe's energy transition. Moreover, the growth in transport and buildings indicates a systemic approach to decarbonization, where clean energy investments are complemented by clean demand-side sectors. It supports economic models of low-carbon transition that emphasize cross-sectoral synergy.

Fig. 15: « Amount Issued by Region »

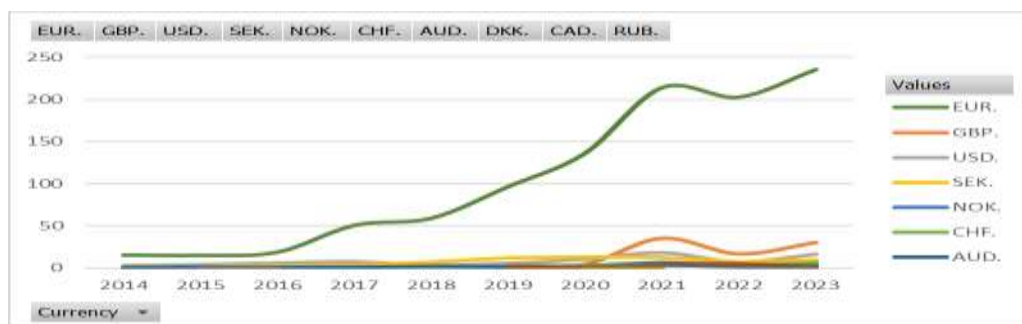


Source: Prepared by Author based on Climate Bonds Initiative 2024.

Europe consistently leads all other global regions in green bond issuance, culminating in \$309.6B in 2023. This positions Europe not only as a regional leader in renewable finance, but also as a global norm-setter in sustainable capital allocation. This financial dominance is underpinned by policies such as the EU Taxonomy, the Sustainable Finance Disclosure Regulation (SFDR), and the Green Bond Standard. These regulatory frameworks have created market confidence, resulting in lower yields for green bonds and expanded issuer diversity.

From a structural economic perspective, this makes Europe's financial markets pivotal to the international green transition, where they serve as both capital originators and policy exporters.

Fig. 16: « Green bonds amount issued By Currency »



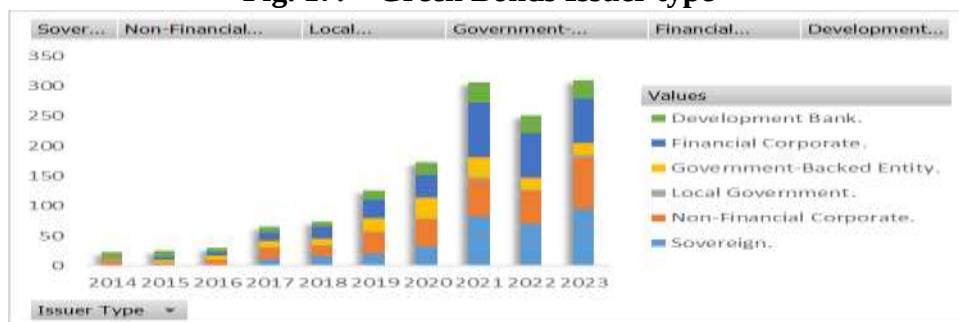
Source: Prepared by Author based on Climate Bonds Initiative 2024.



The euro's predominance in green bond issuance, peaking at €235.7B in 2023, illustrates Europe's monetary commitment to climate finance. The euro is increasingly becoming the de facto global currency for green finance and enhancing the EU's economic sovereignty. This trend offers several macroeconomic benefits:

- It strengthens the euro's position as a reserve currency for climate-aligned investments.
- It supports the European Central Bank (ECB) in integrating climate criteria into its asset purchase programs and collateral frameworks.
- It provides exchange rate stability for green project finance within the Eurozone, thereby reducing financial risks for transnational renewable infrastructure.

Fig. 17: « Green Bonds Issuer type »



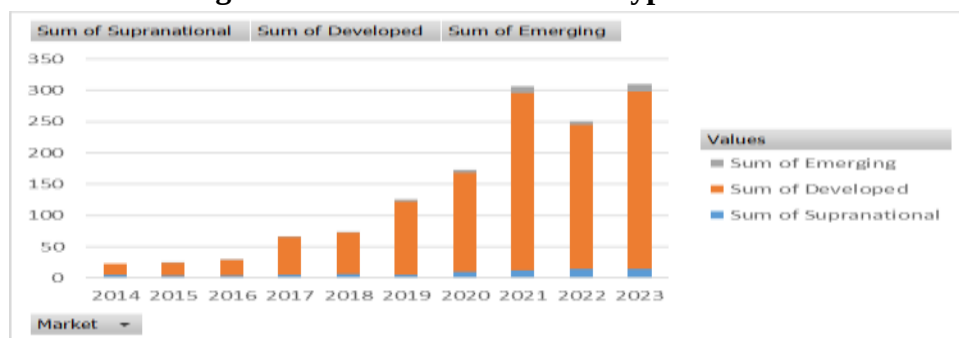
Source: Prepared by Author based on Climate Bonds Initiative 2024.

Although not explicitly listed, typical issuer categories include sovereigns, corporates, municipalities, and supranational institutions (e.g., EIB). Each plays a different role in financing renewables:

- **Sovereigns** (e.g., France, Germany) provide benchmark instruments that de-risk the market.
- **Corporates** issue green bonds to finance renewable project pipelines, especially in the utility and energy sectors.
- **Municipalities** channel green funds into local projects such as solar rooftops, district heating, or EV charging.

This multi-level issuer structure ensures a broad distribution of green capital across scales and sectors, which is essential for an inclusive and resilient energy transition.

Fig. 18: « Green Bonds Market type issued »



Source: Prepared by Author based on Climate Bonds Initiative 2024.



This table showcases the segmentation of the green bond market in Europe by issuer type. Developed markets dominate, reaching \$283.6B in 2023. Supranational institutions (e.g., European Investment Bank) consistently issue around \$10–15B annually, acting as anchor investors and market makers.

Emerging European economies show slower uptake, though has increased post-2020 (e.g., \$11.7B in 2023). This reflects institutional gaps, currency risk, and smaller pipeline projects. However, blended finance and EU-backed de-risking schemes (such as InvestEU) are increasingly enabling emerging markets to enter green bond markets.

The supranational role is critical in lowering borrowing costs and supporting harmonized standards, especially for cross-border renewable energy investments like interconnectors or hydrogen corridors.

Conclusion:

Green bonds have witnessed significant growth and increasing global demand since their emergence, with a wide diversity of issuers, from sovereign states to corporations and financial institutions. In Europe, green bonds have served as a strategic financial tool to bridge the gap between capital providers and clean energy projects, helping to meet climate objectives and promote environmental sustainability.

Throughout the period 2015–2023, Europe allocated the majority of green bond proceeds toward renewable energy investments, particularly in solar and wind power, reflecting the region's strong policy commitment under the European Green Deal and the EU Taxonomy Regulation. Countries such as Germany, France, and the Netherlands have led the way, benefiting from mature capital markets and favorable regulatory frameworks.

- Green bonds in Europe have been key in supporting the region's transition toward a low-carbon economy, aligning with EU climate targets for 2030 and 2050.
- EU regulatory initiatives—such as the Green Bond Standard—ensured that over 90% of proceeds were allocated to green assets, mainly energy, transport, and buildings.
- The market's success has been bolstered by strong institutional support (e.g., European Investment Bank), clear disclosure standards, and increasing investor demand for ESG-compliant instruments.
- In 2023 alone, over \$90.4 billion in green bond proceeds were directed to energy projects, confirming the strong correlation between green finance and renewable energy expansion.
- Europe now stands as the global leader in green bond issuance, with over €309 billion issued in 2023, ahead of all other regions, making it a model for sustainable finance worldwide.

These findings confirm that green bonds are not only a financial innovation, but a strategic pillar in Europe's renewable energy deployment, reinforcing its leadership in climate action and sustainable development.



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